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THE SCIENTIFIC MONTHLY

MAY, 1938

CURRENT MILKY WAY PROBLEMS

By Dr. BART J. BOK
HARVARD COLLEGE OBSERVATORY

THE study of the universe of galaxies has in recent years received so much attention from the writers of popular science that the interested layman might well have formed the opinion that the golden days for work on our own milky way system are over. This is most certainly not so. The available evidence on the general shape and outline of the milky way system appears to be more or less conclusive, and it seems unlikely that our views on these points will undergo radical changes in the near future. At present very little is known, however, about the details of milky way structure. We shall describe briefly in the first section the facts on which our present information on the location of our sun in the milky way system is based, and discuss in subsequent sections our present state of knowledge concerning the motions and distribution of the stars in our system.

1. THE OUTLINE OF THE MILKY WAY SYSTEM

The band of the milky way, which forms one of the finest features of the summer skies in our latitudes, plays a fundamental rôle in all studies of the structure of the particular stellar system to which our sun happens to belong. This milky way system (or, as it is frequently called, our galactic system) comprises all stars visible to the naked eye, and a great majority of the telescopic stars. Not unlike the spiral galaxies, which are observed in great abundance with modern reflectors, our galactic system is highly flattened. Its shape follows roughly the outline of the flattened ellipsoid of revolution shown in the accompanying diagram, in which the location of the sun has been indicated by a cross. Modern observations place the sun at a distance of thirty to thirty-five thousand light years from the galactic center, at a point that is at the most one hundred and fifty light years above the galactic plane. The scale of the diagram does not permit us to indicate the northerly position of the sun and for most practical purposes the sun may be considered as located in the plane of symmetry. What is, briefly, the observational evidence that has led astronomers to agree generally that the shape of our milky way system is approximately as shown in the diagram?

First, let us consider the high degree of flattening of the system. Observations have shown that there exists a considerable range in the average distances of the stars which together give us that magnificent impression called "the milky way." This by itself eliminates immediately the possibility that the milky way as viewed from the sun or earth (their positions are the same, galactically speaking) could be caused by a single starry ring of limited depth, a hypothesis which naturally suggests itself to the untutored

observer. The band-like appearance of our milky way is caused by the high degree of flattening of our galactic system.

Second, how do we know that the sun has an eccentric position in the system? If the sun were anywhere near the galactic center we would expect fairly constant brightness all around the milky way. It is true that some separate star clouds or dark nebulae might cause occasional fluctuations in brightness, but there would be no reason to expect any large-scale variations. We do, however, observe such variations. The half of the milky way from Cygnus through Sagittarius to Carina is very much more brilliant than the other half, which passes through the constellation of Orion. The central portion of the milky way falls clearly in the direction of the constellation of Sagittarius, and it is there that we look at present for the center of the galactic system.

FIG. 1. THE APPROXIMATE SHAPE OF OUR MILKY WAY SYSTEM.

There are several independent lines of evidence which support the hypothesis of the distant center in Sagittarius. The globular star clusters are conspicuously concentrated toward the Sagittarius region, to which Charlier referred as the "home" of the globular clusters. Shapley's work has shown that the globular clusters are among the most distant observable galactic objects, and their concentration toward one hemisphere of the sky suggests that our sun is nowhere near the center of the galactic system. The globular clusters are by no means the only objects that show a decided preference for the milky way regions around Sagittarius. The same phenomenon is exhibited by almost every type of object that can be observed at large distances from the sun. New stars or novae, faint distant variable stars, planetary nebulae, all show a similar concentration.

Further corroborative evidence has been contributed by the theory of galactic rotation. Our galactic system is highly flattened, and this alone is strongly suggestive of rotation of the system as a whole. Oort and Lindblad showed that the existence of such a rotation could be demonstrated from studies on the distribution of the motions of the stars and incidentally proved from their results that the direction toward the center of rotation is somewhere in Sagittarius.

The location of our sun with respect to the center of the galactic system has for many centuries been a point on which the astronomer had no definite information. This has all been changed during the past twenty-five years, and it appears to be highly improbable that the sun will ever be restored to the central position in our galactic system, which it was once supposed to occupy.

There finally remains the matter of the scale of our schematic diagram. Shapley's original investigation suggested a value of well over fifty thousand light years for the distance of the sun from the galactic center, while the first computation from the theory of galactic rotation by Oort gave twenty thousand light years for the same distance. Investigations made since 1929–30 by Trumpler and many others have shown that considerable interstellar absorption is present and that the light from distant objects is dimmed correspondingly. Shapley's original distances of globular clusters should therefore be reduced by approximately thirty per cent. More recent observational material bearing on the theory of galactic rotation (in particular, the radial velocities contributed by Plaskett and his collaborators and by Joy) has shown that Oort's original estimate for the distance of the sun from the galactic center had to be increased. Astronomers are now pretty well agreed that the galactic

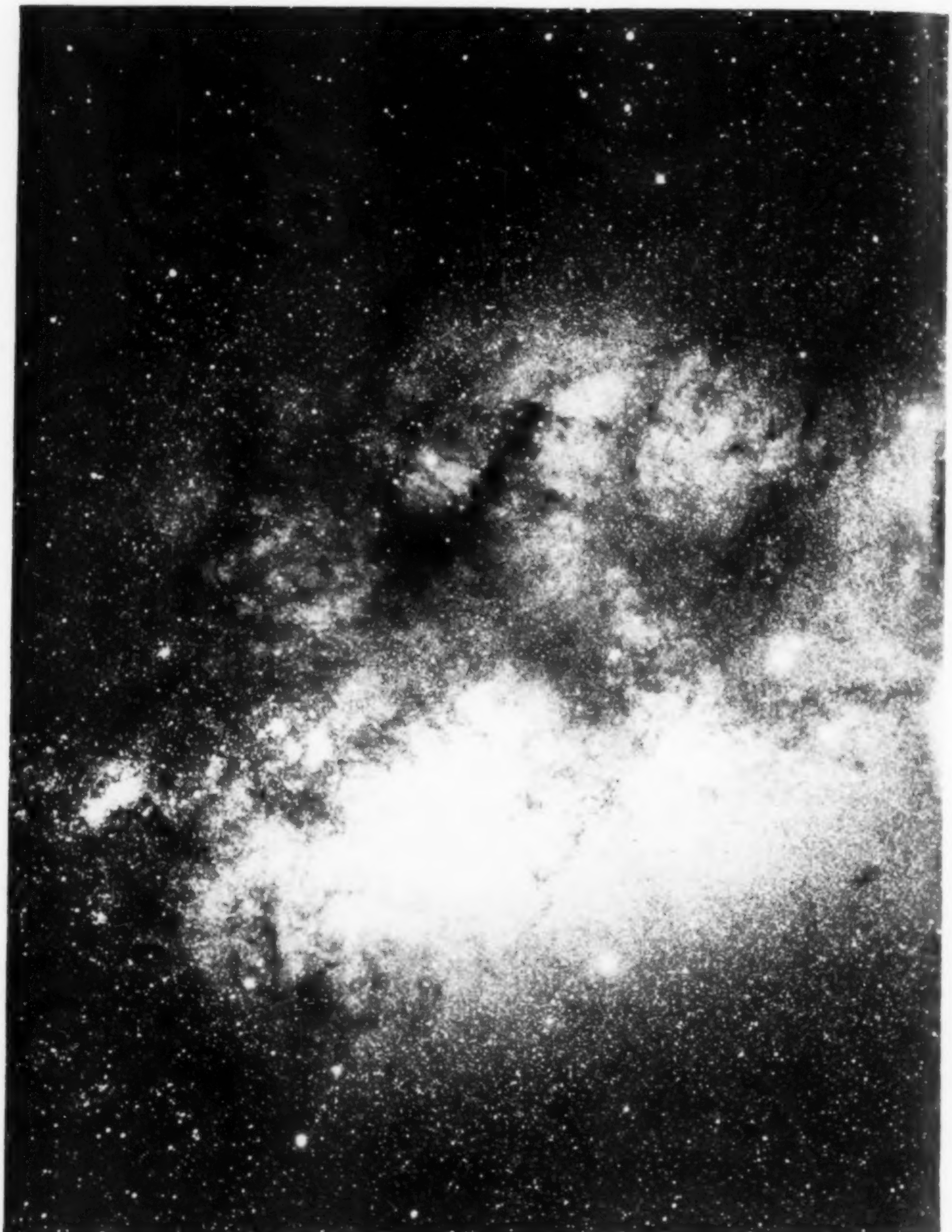
THE GLOBULAR CLUSTER ω CENTAURI

FROM A PHOTOGRAPH TAKEN BY DR. J. S. PARASKEVOPOULOS WITH THE 60-INCH REFLECTOR OF THE BOYDEN STATION OF THE HARVARD OBSERVATORY AT BLOEMFONTEIN, SOUTH AFRICA.

center lies somewhere between thirty and thirty-five thousand light years from our sun. It is impossible to say just where is the outer boundary of our galactic system: the full-drawn line in our diagram is drawn through points where the space density of the stars could hardly exceed a few per cent. of the value near the sun.

It is only natural that the reader will ask further information about some of the details not shown in the schematic diagram. Is our galactic system a spiral nebula? Do separate star clouds exist in the system? What is known about the interstellar medium, which apparently plays an important part in studies of galactic structures? Unfortunately, it is impossible to give straightforward answers to these questions now. We can, however, discuss the problems that currently have the attention of the galactic investigators, and show in this fashion not only what progress has already been made, but also where further research is most urgently needed.

There is a broad division into two groups of problems, the first of which includes investigations dealing with galactic structure, whereas the questions relating to stellar motions and the dynamical properties of the system form a second division. The appearance of the milky way is influenced to a considerable extent by the presence of absorbing material which either partly or totally hides distant galactic objects from our view. We shall therefore precede the discussion of the problems of galactic structure and stellar motions with a brief survey of our knowledge of the interstellar medium.



THE REGION OF THE GREAT STAR CLOUD IN SAGITTARIUS

FROM A PHOTOGRAPH TAKEN WITH A $1\frac{1}{2}$-INCH COOKE LENS. MORE THAN ONE QUARTER OF ALL KNOWN GLOBULAR CLUSTERS FALL WITHIN THE LIMITS OF THE REGION SHOWN ON THIS PLATE, WHICH COVERS AN AREA OF ONLY TWO PER CENT. OF THE ENTIRE SKY.

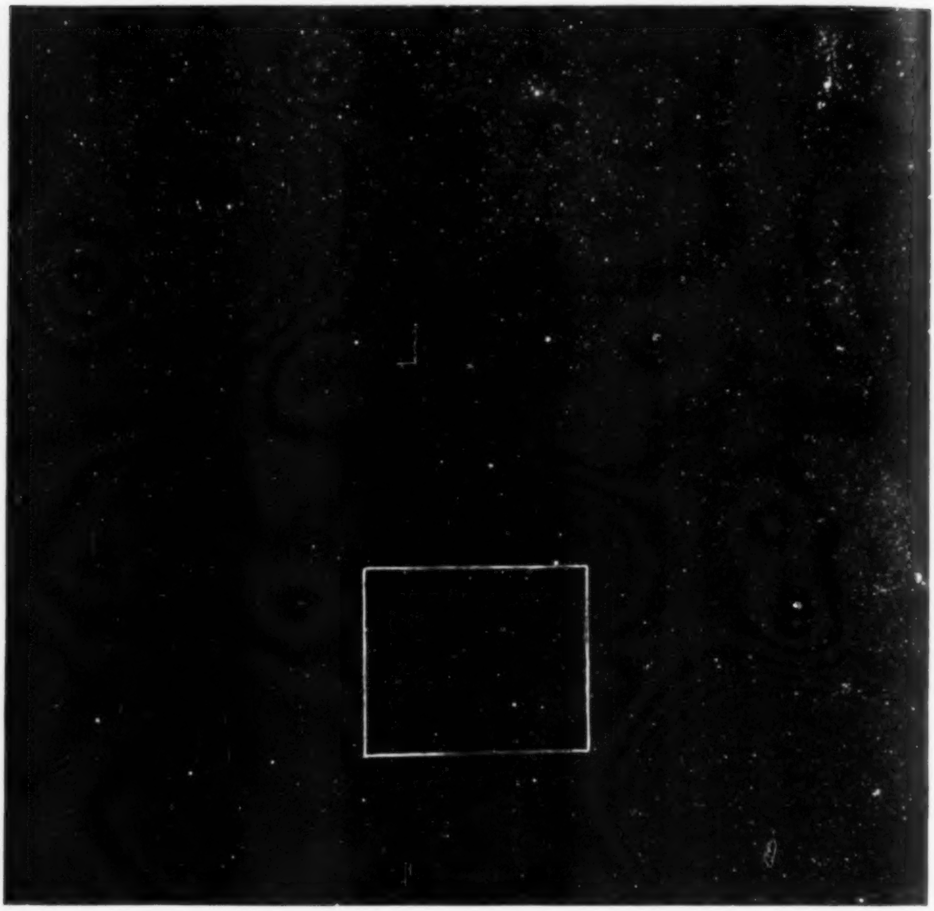
2. The Interstellar Medium

The particles which inhabit the regions between the stars vary all the way from tiny electrons and atoms to meteoric particles of the size of an average pin-head. The blocking of the light of distant galactic objects is caused neither by single atoms or electrons nor by meteoric particles, but it has been shown that particles with dimensions of the order of one tenth to ten times the wave-length of visible light are chiefly responsible. If a dense cloud of large meteoric particles were between the earth and a distant star, the star would appear fainter because of the resultant absorption, but no change in color would be observed. If the same cloud were to consist of particles with dimensions small compared to the wave-length of visible light not only would the star appear fainter, but its light would become distinctly reddened. Every one is familiar with the last type of scattering of light; the small particles in the earth's atmosphere scatter the blue waves in the light of the sun more effectively than the red ones, an effect which for example, causes the setting sun to be red and the sky to be blue. The degree of reddening accompanying a given total amount of absorption for photographic light is a measure for the particle sizes of the most effective absorbers.

There are several types of luminous stars for which the intrinsic colors can be predicted from spectral studies. The measured colors of such objects will yield information on the change in color caused by the passage of the light through the interstellar medium, and give definite clues for the derivation of the distribution of particle sizes. Valuable contributions have been made by Stebbins, Trumpler, Struve, Schalén and many others, and the presence of a slight amount of space reddening has been established. It is from the observational studies of colors of distant stars that our knowlege of the average particle sizes has been derived.

The galactic investigator is primarily interested in the effect of the interstellar absorption on the appearance of the milky way and hence wishes to know what corrections for interstellar absorption should be applied in the analysis of data on stellar distribution. We turn therefore now to those investigations which have led to a determination of the total amount of dimming of star light in the photographic region of the spectrum for various directions in the milky way. If we know both the amount of the change in color and the law of variation of absorption with wave-length, it becomes a simple matter to compute the total absorption of photographic light. More direct methods for the derivation of the total photographic absorption should, however, be preferred as long as we have only meager information on the law of variation of extinction for separate wave-lengths.

In the original investigation, which led to the general acceptance of the presence of a considerable general absorption of light near the galactic plane, Trumpler made use of measurements of diameters for galactic star clusters. Such diameter estimates are unfortunately rather arbitrary, but in spite of the difficulties involved Trumpler's original value for the coefficient of interstellar absorption has stood up remarkably well. The most dependable value for the average coefficient of absorption can now be obtained from the galactic rotation effects in the radial velocities of distant stars and nebulae (Joy, Berman); it is found that the coefficient of absorption for photographic light amounts to one quarter of a stellar magnitude for a distance of one thousand light years. The analysis of the available data on star counts shows that it is extremely unlikely that the value of the coefficient will exceed three tenths of a



THE REGION OF THE SOUTHERN GALACTIC WINDOW

WITHIN 25° OF THE GALACTIC CENTER, DISCOVERED BY SHAPLEY IN THE COURSE OF THE HARVARD SURVEY OF FAINT EXTERNAL GALAXIES. THE WHITE LINES MARK THE PARTICULAR AREA IN WHICH MANY FAINT EXTERNAL GALAXIES HAVE BEEN FOUND. A STRIKING FEATURE OF THE PHOTOGRAPH IS THE LACK OF ANY VISIBLE EVIDENCE FOR DIFFERENCES IN THE STELLAR DISTRIBUTION BETWEEN REGIONS IN AND AROUND THE WINDOW, WHICH IS CONFIRMED BY ACCURATE STAR COUNTS. THE MOST PROBABLE CONCLUSION IS THAT THE INTERSTELLAR ABSORPTION IN THE PARTLY OBSCURED REGIONS ON EITHER SIDE OF THE WINDOW IS NOT VERY LARGE.

magnitude. The average coefficient holds for regions close to the galactic plane, and it can be shown from the distribution of stars and nebulae away from the plane that the effective thickness of the galactic absorbing layer is certainly not in excess of two thousand light years.

At present we are, however, no longer so very much concerned with the average coefficient of absorption, but the attention is gradually being focused upon the variations in the amounts of interstellar absorption from one region to the next. A glance at any milky way photograph will convince the reader better of the importance of fluctuations in the interstellar absorption than could a long preamble. The characteristic feature of all milky way photographs is that of marked irregularities in stellar distribution.

Dark lanes and regions of star-deficiency are present on all such photographs and one of the main problems of to-day is to decide what fraction of the general interstellar absorption arises in isolated dark nebulae. Around 1930 most astronomers were of the opinion that a smooth continuous medium was probably responsible for the interstellar absorption. This has gradually changed, and there is now a considerable following for the hypothesis that isolated dark nebulae may account for at least 50 per cent. of the total interstellar absorption. Several reasons have led to this change of opinion.

It was only natural, at the time that the suggestion of general interstellar absorption was first put forward, to assume a more or less uniform distribution of the interstellar medium and obtain in this way at least some information about its most general properties. It might have been expected that more refined studies would lead to modifications in the first crude hypothesis. Astronomers have during the past ten years paid considerable attention to the study of isolated dark nebulae. The survey has not been finished by any means, but already we can see that the known nebulae alone contribute significantly to the general absorption. Some of the isolated dark nebulae cover tremendous areas of the sky; the dark nebulae in Ophiuchus and Scorpio cover an area of one thousand square degrees of the sky, which is equivalent to five thousand times the area covered by the full moon. The light of the stars beyond these tremendous dark nebulae is dimmed by at least a full magnitude.

Further evidence for the importance of condensations in the interstellar medium has come from studies of the distribution over the sky of distant external galaxies. There are literally millions of such objects within the reach of modern telescopes. Each galaxy that is found on one of our photographs (there are sometimes more than a thousand on one single plate!) is again a stellar system not unlike our own galactic system. These external galaxies are extremely numerous away from the galactic plane, but it has long been known that their frequency decreases as we approach the band of the milky way. Our own milky way system is only one of many and it would be downright silly to suppose that our particular galactic plane would be a plane of symmetry in the universe of galaxies. The lack of external galaxies near the band of the milky way is caused by our galactic interstellar medium, which simply screens off the light of distant external galaxies. The absence of the galaxies near the band of the milky way gives therefore proof for the existence of an interstellar absorbing medium.

This is all an old story, but in recent years the studies of the distribution of faint external galaxies at Mount Wilson and at Harvard have given further information about the interstellar medium which has led to the discovery of what Shapley calls so aptly "galactic windows." A galactic window is a region close to the band of the milky way, where rather unexpectedly external galaxies pop up in great numbers. The fact that we see these nebulae is by itself evidence that, in that particular direction, the density of the absorbing medium should be very small. In a few regions near the galactic circle we observe many such galaxies, while in neighboring fields we do not find a single one. This is all very puzzling, if we assume that there exists a smooth, continuous interstellar medium, but the discovery of galactic windows can be interpreted as that of "the holes in between the clouds," if the absorbing medium is supposed to be composed of isolated dark nebulae.

Obviously one of the most important future problems is to make a complete survey of the distribution of faint external galaxies within twenty degrees of the

galactic circle. This, together with the survey of the distribution of isolated dark nebulae, should go far toward unraveling the remaining mysteries of the absorbing interstellar medium.

3. Structural Problems

It is necessary to have full information on the properties of the absorbing medium before we can tackle with any hope of success the problems of the distribution of the stars in space. Our present data on interstellar absorption are unfortunately far from complete, and it is very much easier to write down a list of topics that await further study than it would be to make some positive remarks about the distribution of the stars at various points in the galactic plane.

If we know for a given direction the amount of absorption at various distances from the sun, it is possible to find the run of the star densities for that direction from the analysis of star counts, or from studies on the distribution of spectral types and colors. Because of the fluctuations in star density and absorption from one region to the next, we can not expect to obtain significant results from analyses of distributions which represent averages for many galactic fields. It is safe to predict that our knowledge of galactic structure will be advanced most rapidly by detailed investigations of regions of limited extent.

The equipments of several of the larger American observatories are excellently suited for investigations of this type. Star counts for large fields can be obtained to the fifteenth magnitude with a four-inch photographic camera; and while it would be too time-consuming to count all stars to the nineteenth or twentieth magnitude, it is a simple matter to obtain counts for a few sample regions with a larger reflector or refractor. Spectral types can be obtained for all stars to the twelfth magnitude, and, with a little extra effort, it is quite possible to extend the survey for some small regions to the fourteenth magnitude. Color observations for the same stars present no difficulty; and since it is possible to deduce true colors and approximate absolute magnitudes from the spectral types, a comparison between the true and observed colors will yield directly information on the reddening caused by interstellar absorption for the field under investigation. The star counts give further data on the distribution of isolated dark nebulae, and by adding surveys for the distribution of faint external galaxies, the absorption properties of the field become known. It is then a straightforward process to derive the density distribution for the stars at large from star counts and, from the spectral survey, for each spectral type separately.

Studies of proper motions and radial velocities, as well as investigations of the distribution of variable stars, have not been included in the above program, but would be a considerable help for the final analysis. The proper motions would make possible the separation of giants and dwarfs among the cool stars, the nearby dwarfs showing on the average much larger angular displacements than the distant giants. The proper motions might also help further in the absorption analysis, but recent work along this line has not been too encouraging. Radial velocities of faint stars can be determined in great numbers with the objective prism method that has recently been developed as a working tool at Harvard. These velocities provide a check on the absorption properties of the field if the galactic-rotation term happens to be large enough. They will be of importance for a further dynamical interpretation of the observed density distribution. Studies of the distribution of variable stars would finally aid particularly in investigations of limited regions of high star density.

THE SOUTHERN MILKY WAY FROM CARINA TO CENTAURUS

THE CONSPICUOUS DARK NEBULA CALLED THE "COAL SACK" CAN BE SEEN NEAR THE CENTER OF THE PHOTOGRAPH. TO THE RIGHT AND SLIGHTLY ABOVE THE COAL SACK-NEBULA ONE IDENTIFIES THE SOUTHERN CROSS WHICH, BECAUSE OF THE REDNESS OF TWO OF ITS MEMBERS, IS NOT SO CONSPICUOUS ON PHOTOGRAPHS AS TO THE NAKED EYE. THE BRIGHT STAR IN THE BAND OF THE MILKY WAY NEAR THE LEFT EDGE OF THE PHOTOGRAPH IS α CENTAURI, ONE OF THE NEAREST NEIGHBORS OF OUR SUN. THE DIFFUSE NEBULA NEAR η CARINAE (SEE NEXT PLATE) IS SHOWN AS A FUZZY OBJECT CLOSE TO THE RIGHT EDGE OF THE PHOTOGRAPH.

I could go on and enter into more details, but I hope to have succeeded in demonstrating that modern astronomical technique enables us to attack successfully the problem of the density distribution for a region of limited size. What regions will it be well to pay particular attention to? First on the list come undoubtedly the galactic windows, in which the absorption bugaboo does not bother us at all; second, the regions near the galactic plane apparently not affected by isolated dark nebulae; and third, regions within fifteen degrees of the galactic circle which are free from the influence of obscuration.

It was shown earlier in the present article that we are reasonably well informed on the general outlines of our galactic system, but that our knowledge of the structural details is practically nil. The best we can do is to indicate the types of problems in galactic structure that may be considered as more data are gradually becoming available.

1. The local system: It has long been known that, if we disregard the presence of interstellar absorption, the observed run of star counts to the twelfth magnitude indicates a rapid decrease in the star density with increasing distance from the sun for every direction in the galactic plane. The first thought of many astronomers after the discovery of interstellar absorption must have been that now there was an opportunity to get rid of those negative density gradients, which indicated formerly a rather peculiar position of the sun in the galactic system. Subsequent investigations, based largely on star counts assembled by Kapteyn, van Rhijn and Seares, did not confirm this guess. There remained unmistakable indications that the sun is near a region of high star density and that the density drops rapidly in some directions away from the sun, particularly in the directions toward, and diametrically opposite from, the galactic center. No very pronounced drops are, however, found along a line passing through the sun in a direction perpendicular to that to the galactic center; the star densities appear to be reasonably constant over a distance of at least five thousand light years in a direction toward the constellations of Cygnus and Carina. Does this observation indicate that our sun is part of a finite local system elongated along the line Cygnus-Carina, *i.e.*, in a direction perpendicular to that of the galactic center? This is an attractive hypothesis, and the picture of local system elongated because of the rapid whirls in our rotating galaxy has considerable appeal. We have, however, no information whatever as to what happens beyond five thousand light years, and it is not at all impossible that our local system is only a small part of a giant spiral arm passing through our sun.

The first job will be to study more carefully the density distribution for various directions in the galactic plane. Data on the individual parallaxes, proper motions and radial velocities are accumulating rapidly for the brighter stars; at the same time large amounts of material on colors, the distribution of spectral types and general star counts are becoming available for the fainter stars. Before long it should be possible to establish or disprove beyond reasonable doubt the reality of the local system.

2. Star clouds: The irregular appearance of the milky way has led to the designation of certain regions of high star density as the Cygnus cloud, the Scutum cloud, etc. Is our milky way perhaps an aggregate of star clouds? The hypothesis of galactic rotation does not favor such a hypothesis, since it can be shown that most star clouds would be disrupted within a few galactic revolutions by the tidal forces of the galactic nucleus. But then, the theory of galactic rotation may be partly wrong and the matter of the reality of star clouds should be decided on the basis of the data on stellar dis-

tribution and not by some roundabout theoretical argument.

The suspected star clouds are without exception at such large distances from the sun that it will take highly effective use of the world's largest telescopes to obtain data for the crucial test as to the reality of these clouds. We know already that the apparent boundaries of several star clouds are caused in part by the presence of near-by dark nebulae, which simply screen off the light of remote stars in certain directions. Few star clouds have as yet been investigated completely, but a recent analysis of the stellar distribution in the constellation of Cygnus by Miller shows that the Cygnus cloud will probably have to be removed from the list of the real star clouds. While some giant star clouds are in danger of being disqualified as such, there will undoubtedly remain a good many smaller condensations of which the reality can not be denied. Particularly some of the highly luminous stars appear to prefer to come in bunches and it seems almost certain that these condensations are real.

The types of observations that should be made in order that the controversy about the star clouds may be settled are very much the same as those suggested for the study of the local system. Only —the magnitude limits for the various surveys should be at least two magnitudes fainter than those set for the local system surveys.

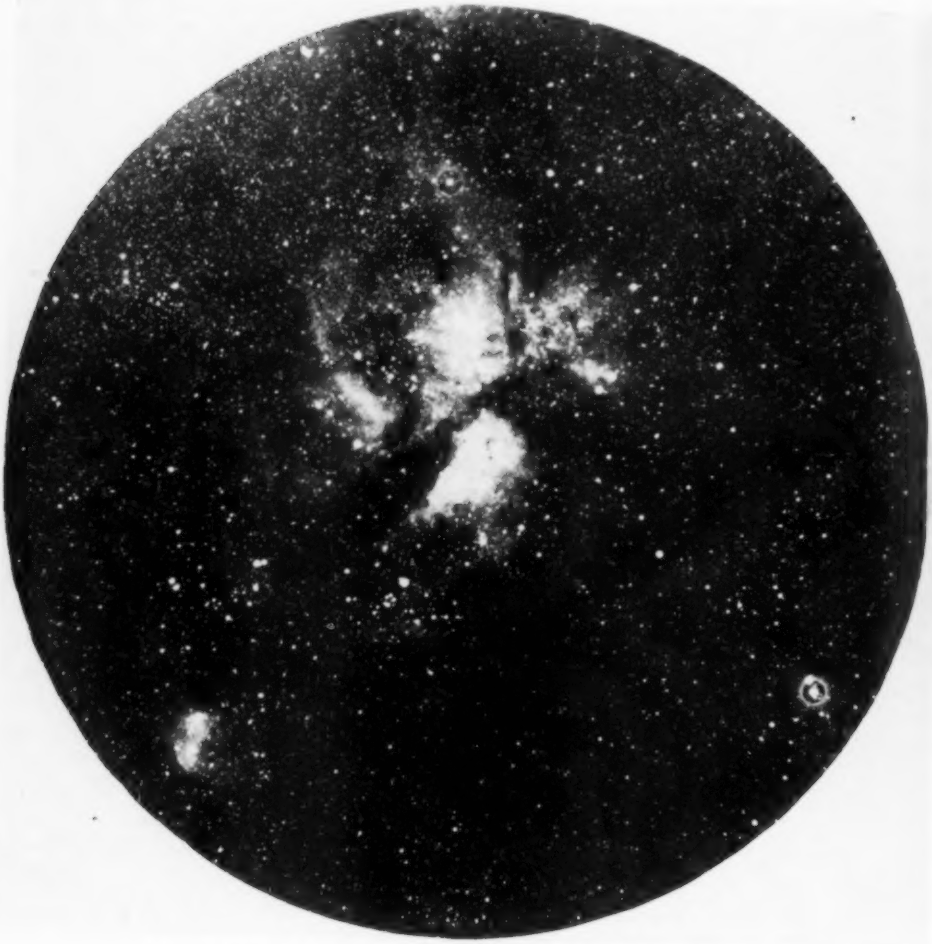
3. The galactic nucleus: Shapley's work on the globular clusters and the Oort-Lindblad theory of galactic rotation suggest the presence of a massive galactic nucleus at a distance of thirty to thirty-five thousand light years from the sun in the direction toward Sagittarius. The great star cloud in Sagittarius has commonly been identified as the galactic nucleus. There is little doubt but that the center of our milky way system is located in a direction which differs by not more than ten degrees from that toward the Sagittarius cloud, but several considerations indicate that we may not have yet observed the real galactic nucleus at all.

Star counts and studies of the distribution of spectral types suggest that a drop in the star density in the direction of the Sagittarius cloud stops at a distance of the order of two to three thousand light years and is followed by a steep rise, which sets in at approximately five thousand light years from the sun. Beyond this there comes, in all probability, a region of continued high density. This observation suggests that the main body of the great star cloud of Sagittarius is considerably closer to us than the galactic center.

The original evidence for the Sagittarius cloud's being the galatic nucleus was based upon observations of variable stars. Unfortunately there is not much information available on the distribution of absorbing matter for that particular region of the sky, and the analysis of the available data is correspondingly difficult. The study of the distribution of spectral types in the Sagittarius cloud has been undertaken by Wallenquist, but it is to be hoped that his work will be supplemented by investigations with some of the largest reflectors.

The galactic nucleus should not necessarily be an approximately spherical star cloud with a radius of the order of two to four thousand light years. Lindblad has shown, from dynamical considerations, that it is very likely that the nucleus of a rotating galaxy would become highly flattened. In fact, it might be so flattened that its outer edge might come to within ten thousand light years of the sun. All the more reason to attempt detailed studies of this part of the sky with large reflectors.

Even if it were so that absorbing matter would shield the galactic nucleus forever from our view, there are still two ways open for ascertaining the mass and



THE DIFFUSE NEBULA NEAR THE STAR η CARINAE
A PHOTOGRAPH TAKEN SEVERAL YEARS AGO WITH THE 13-INCH BOYDEN REFRACTOR AT AREQUIPA, PERU.

dimensions of this nucleus. Studies of the radial velocities of distant objects like faint variable stars (Joy) or planetary nebulae (Berman) have already shown that much information on the distribution of matter in our galactic system can be obtained from the variations in the average radial velocities of certain groups of distant stars and nebulae. A second way has been suggested by Oort in connection with the distribution of stellar velocities perpendicular to the galactic plane for objects at large distances above or below the plane. These velocities are to a great extent governed by the gravitational pull exerted by the galactic nucleus. It is indeed not impossible that careful studies of objects in the star-empty regions around the galactic pole may give the most reliable information on the nucleus of our milky-way system.

4. Stellar Motions and Galactic Dynamics

It was necessary to mention evidence

THE SAME DIFFUSE NEBULA

AS SHOWN ON ADJACENT PAGE. A PHOTOGRAPH TAKEN QUITE RECENTLY WITH THE 60-INCH REFLECTOR AT BLOEMFONTEIN, SOUTH AFRICA.

relating to stellar motions in connection with some of the typical structural problems that have already been considered. There exists, however, a group of galactic problems which deals specifically with the state of motion in our milky-way system and which may properly be discussed under the present heading.

The Oort-Lindblad theory has been remarkably successful in explaining the great majority of the observed regularities in the distribution of the stellar motions. The underlying conception is that of rotation around the galactic nucleus. A star like our sun moves approximately in a circle around the galactic center, with a rotational speed of the order of one hundred and fifty miles per second; the period of a single galactic revolution is for our sun of the order of two hundred million years. Because of the considerable concentration of mass in its nucleus the galactic system does not rotate like a solid wheel, but, according to Oort and Lindblad, the period of rotation decreases as stars that are, on the aver-

THE LARGE MAGELLANIC CLOUD

WHICH CAN BE CONSIDERED AS A SATELLITE OF OUR OWN MILKY WAY SYSTEM. SINCE IT IS OUR NEAREST EXTRA-GALACTIC NEIGHBOR IT IS POSSIBLE TO MAKE DETAILED STUDIES OF ITS STRUCTURAL FEATURES. THIS PLATE SHOWS THE APPEARANCE OF THE CLOUD AS A WHOLE. THE WHITE ARROWS POINT TO THE DIFFUSE NEBULA KNOWN AS 30 DORADUS, WHICH IS ALSO SHOWN ON ADJACENT PAGE.

age, closer to the galactic center are being considered. Viewed from the sun certain stars will appear to be running ahead, others will appear to be lagging behind, and some simple geometrical considerations show immediately what types of systematic effects should be observed in the average radial velocities and proper motions of stars at not too large distances from our sun.

The theory of galactic rotation was originally developed by Lindblad as a means for explaining a pronounced asymmetry in the distribution of stellar motions in the galactic plane which had been revealed by the work of Boss, Strömberg and Oort. It has been shown that the velocities in excess of forty miles per second with respect to our sun were all pointed toward one half of the galactic circle. The phenomenon of all high velocity stars rushing off toward one half

THE DIFFUSE NEBULA 30 DORADUS

IN THE LARGE MAGELLANIC CLOUD SHOWN ON ADJACENT PAGE. THIS PHOTOGRAPH IS FROM A PLATE BY DR. J. S. PARASKEVOPOULOS WITH THE 60-INCH REFLECTOR AT THE SOUTHERN STATION OF THE HARVARD OBSERVATORY. THE DISTANCE OF THE LARGE CLOUD IS ABOUT 85,000 LIGHT YEARS, ITS DIAMETER IS AT LEAST 15,000 LIGHT YEARS AND THE DIAMETER OF THE DIFFUSE NEBULA AMOUNTS TO 130 LIGHT YEARS.

of the milky way baffled astronomers until Lindblad hit on an explanation which in its simplest form is illustrated by the accompanying diagram.

G is the center of the galactic system, S is a star in neighborhood of the sun; the distance SG is therefore of the order of thirty-five thousand light years. If the velocity of the star S were equal to one hundred and fifty miles per second, the star would move in a circle around G. Our sun and the great majority of the nearby stars move apparently in such circular paths around the galactic center. There will of course be deviations from exact circular motion for each individual star, but the distances to the galactic center will, for most stars in the vicinity of the sun, vary by not more than five or ten thousand light years in the course of a few galactic revolutions.

Consider now the stars with velocities of (respectively) one hundred and two hundred miles per second around the galactic center. A velocity of one hundred miles per second at our sun will not

be sufficient to carry the star around in a more or less circular orbit, and the resulting orbit will have the elongated shape illustrated in the diagram. Such slow-moving stars do exist: an observer on our sun will recognize them as "high-velocity objects," which, viewed from his standpoint, have velocities of the order of fifty miles per second in a direction *opposite* to that of the general galactic rotation. The observed phenomenon of asymmetry shows that we do not find any stars that move with speeds of the order of fifty miles per second with respect to our sun *in* the direction of rotation. Such stars would have velocities of the order of two hundred miles per second with respect to the galactic center and the hypothesis of galactic rotation suggests that the gravitational pull of the galactic nucleus would be too small to keep them permanently in our system.

The simple explanation for the phenomenon of asymmetry in stellar motions can be refined in several ways, but the rough argument serves to show how this asymmetry is a natural consequence of the rotation of our galactic system. Astronomers had tried in vain to explain the asymmetry on the assumption that the motions of the stars near the sun were governed by the gravitational pull exerted by these same stars. The Oort-Lindblad theory showed that a distant galactic nucleus was the chief controlling factor.

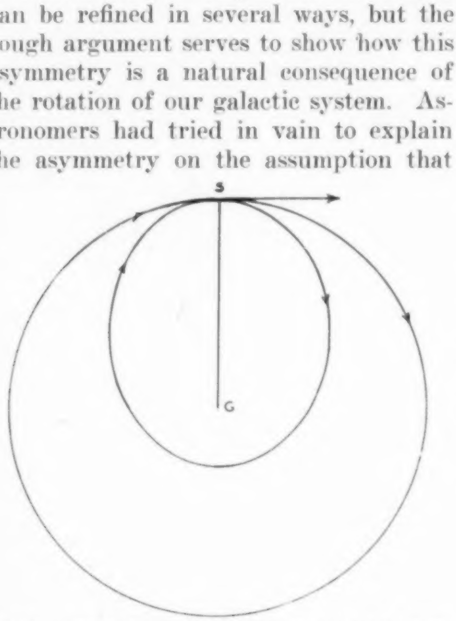
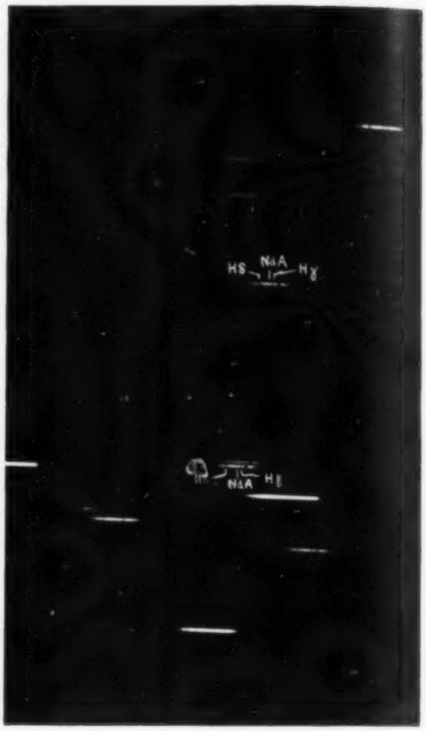


FIG. 2. THE THEORY OF GALACTIC ROTATION ORIGINALLY DEVELOPED BY LINDBLAD. *G* IS THE CENTER OF THE GALACTIC SYSTEM, *S* IS A STAR IN THE NEIGHBORHOOD OF THE SUN.



A PORTION OF A PLATE USED FOR THE DETERMINATION OF RADIAL VELOCITIES FROM OBJECTIVE PRISM SPECTRA FOR A FIELD IN MONOCEROS. THE PHOTOGRAPH WAS TAKEN BY DR. J. S. PARASKEVOPOULOS AT THE SOUTHERN STATION OF THE HARVARD OBSERVATORY WITH A SIX-DEGREE PRISM ATTACHED IN FRONT OF THE LENS OF THE 13-INCH BOYDEN TELESCOPE. THE ABSORPTION BAND MARKED "ND A," WHICH LOOKS VERY MUCH LIKE ONE OF THE STELLAR LINES, IS CAUSED BY THE PASSAGE OF THE STAR LIGHT THROUGH A LIQUID FILTER DIRECTLY IN FRONT OF THE PLATE WITH A SOLUTION MADE OF NEODYMIUM CHLORIDE. THE BAND ND A WILL HAVE THE SAME WAVELENGTH IN ALL STELLAR SPECTRA, WHEREAS STELLAR LINES H γ AND H δ WILL BE DISPLACED ACCORDING TO THE STAR'S RADIAL VELOCITY; ACCURATE MEASUREMENTS OF THE DISTANCES BETWEEN ND A AND H γ OR H δ WILL LEAD TO A DETERMINATION OF STELLAR RADIAL VELOCITIES.

Lindblad pointed out that the theory could also account in a satisfactory fashion for the two star streams, discovered by Kapteyn in the first decade of the present century. When Oort succeeded in demonstrating from the observed stellar motions that the predicted variations in the average velocities of distant stars existed, the theory of galactic rotation could rightfully boast of three major victories. But again there remained, and still remains, a lot to be done!

The primary need is for further data about the line-of-sight velocities of distant objects. Important contributions have been made in recent years by Plaskett (giant stars with high temperatures), Joy (faint Cepheid variables) and Berman (planetary nebulae). The results of these studies have strengthened the observational foundations on which the hypothesis of the rotation of our galaxy is based. The two outstanding defects of the available material are: (1) an insufficient number of velocities for faint stars; (2) an uneven distribution of the stars with known velocities along the milky way. A distressing lack of radial velocity data in the southern hemisphere has arisen because of the location in northern latitudes of most of the telescopes used for radial velocity work. A large British observatory to be established in South Africa near Pretoria will undoubtedly do its best to fill in that particular gap. Also, during the past two years the objective-prism method of obtaining radial velocities for large numbers of faint stars has been adapted for use with the Harvard Observatory's instruments at the station at Bloemfontein, South Africa. There is now in progress at Harvard a study of the distribution of the radial velocities of a thousand stars in twelve fields, located at intervals of thirty degrees around the entire milky way.

Highly significant results may be expected from investigations dealing with the velocities of very distant stars and nebulae. The theory of galactic rotation predicts for such objects certain deviations from the simple effects observed for the stars within five thousand light years of our sun. It should be possible to obtain information on the distribution of mass in the galactic nucleus, if we can observe stars near enough to the galactic center. Valuable results may be expected from the measurements of radial velocities for galactic clusters (Trumpler) and globular clusters (Mayall) which are under way at the Lick Observatory. It will, however, be advisable in the interpretation of the data of observation not to place too much implicit faith in the simple theory of galactic rotation. The Oort-Lindblad theory supposes our milky-way system to be a structureless affair in which a massive nucleus alone determines the motions of the stars. The case is not unlike that of the smooth all-pervading interstellar medium that was originally held responsible for all absorption phenomena. The smooth medium was soon forced to abdicate in favor of the complex interstellar medium revealed by recent studies, and the same fate will undoubtedly await the simple theory of galactic rotation.

The nearby stars should also come in for their share of attention. Several observatories have undertaken the time-consuming job of providing further velocity data for the stars within two or three thousand light years from the sun. Before another decade will have passed we may count on having detailed information on the local irregularities in the distribution of stellar velocities. These observations may well yield the information needed for the formulation of a hypothesis on the distribution of stellar motions that takes into account some of the more complex features of galactic structure.

Apparently this is the age in which the galactic investigator is constantly clamoring for more observational material. At the same time it is well, however,

THE SPIRAL NEBULA MESSIER 83

A RECENT PHOTOGRAPH OF THE SPIRAL NEBULA MESSIER 83, TAKEN WITH THE 60-INCH REFLECTOR AT THE BOYDEN STATION OF THE HARVARD OBSERVATORY. THE APPEARANCE OF OUR MILKY-WAY SYSTEM, AS VIEWED BY AN ASTRONOMER LIVING SOMEWHERE IN MESSIER 83, MAY NOT BE UNLIKE THAT SHOWN IN THE ABOVE PHOTOGRAPH.

to remember the need for further theoretical investigations. Our galactic system may be a spiral nebula. What state of motion is to be expected in such a nebula? How did the many spiral nebulae that are known come into existence and what guesses can we make about their possible development? Such questions lead to dynamical studies of great difficulty, to which Lindblad has paid particular attention during recent years. It appears that the good old Newtonian law of attraction may after all succeed in explaining the nature of spiral arms and that there will be no need to invent mysterious "cosmic forces" to account for the prevalence of spiral structure in the universe of galaxies.

A second theoretical question that still keeps astronomers guessing is related to the origin of our milky way system. It has long been known that there exists a correlation between the velocity characteristics of the stars and their physical properties. For instance, there are indications that the blue-white giant stars move in more or less circular orbits around the galactic center, while the red giants appear to prefer more elongated ones. Also we find among the Cepheid variable stars that the variables with periods of light variation of the order of ten days move in circular paths, whereas Cepheids with periods around one day are found to have orbits that are definitely elongated. This difference must be somehow related to the beginning of our galactic system and the origin of stars. At present it does seem absurd that the periods of light variation, which depend on conditions in the stellar interiors, should be correlated with the speeds of the stars. But absurd or not, we have to face the facts and we should admit that we have as yet mighty little to offer for an explanation.

A question of great importance for all theoretical studies of our galactic system is that of its probable age. A most delicate question indeed! This is not the place to go into details about the controversial subject of the age of the universe, but it is well to remember in all theoretical investigations that our sun has probably not gone more than twenty times around the galactic center. The stars still exhibit a surprising degree of parallelism in the distribution of their motions. This in itself offers pretty good evidence that our system is still fairly young. As time progresses stars should influence one another's motions to a considerable extent; it is for instance difficult to understand how the members of the loosely-connected Hyades cluster could continue to run very nearly parallel for more than a few galactic revolutions. Several independent lines of evidence suggest that approximately three billion years ago our galactic system underwent some rather drastic punishment. What exactly did happen at that time? That is just another problem for the astronomer to solve, but before we tackle it we had better get first some more information on what goes on right now.

The recent advances in our knowledge of galactic structure have been brought about largely by the development of very efficient instruments. The progress of the past forty years has depended at each point on refinements and improvements in the technique of observation. The total amount of information that is needed is so large that there simply has not yet been enough time to get it together. The gaps in our knowledge are, however, being filled in rapidly, and I can only hope that the answers to some of the problems which I have posed may make interesting reading before another decade will have passed by.

LIFE IN THE SEA. II

By Dr. R. E. COKER

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GASES IN SOLUTION

The chief gases dissolved in the sea are nitrogen, oxygen and carbon dioxide. Nitrogen is said to occur in sea water in somewhat smaller proportion (64 per cent.) to other gases than in the air (78 per cent.), but in approximately saturated solution. Oxygen is about one fifth less soluble in sea water than in fresh water, but it is absorbed in sea water in a proportion to other gases (34 per cent.) substantially greater than in the air (21 per cent.). The percentages given apply to sea water at the surface with salinity of 3.5 per cent. and temperature of 10° C. These figures, indicating the proportion of the several gases relative to one another in dissolved, as compared with atmospheric air, are perhaps of less practical significance than are those indicating the volumes of oxygen in a liter of sea water at the point of saturation—and this varies with the temperature, the pressure and the salinity. At any given temperature and pressure, sea water can hold in solution less oxygen (about one fifth less) than can fresh water, as is indicated by Table II. (After Fox, from Murray and Hjort, p. 254).

TABLE II

SOLUBILITY OF OXYGEN IN FRESH AND SEA WATER AT DIFFERENT TEMPERATURES*

Temperature	Fresh-water salinity 0 per M.	Sea-water salinity 35 per M.
0°	10.29	8.03
10°	8.02	6.40
20°	6.57	5.35
30°	5.57	4.50

* Under conditions of atmospheric mixture and under a pressure of one atmosphere.

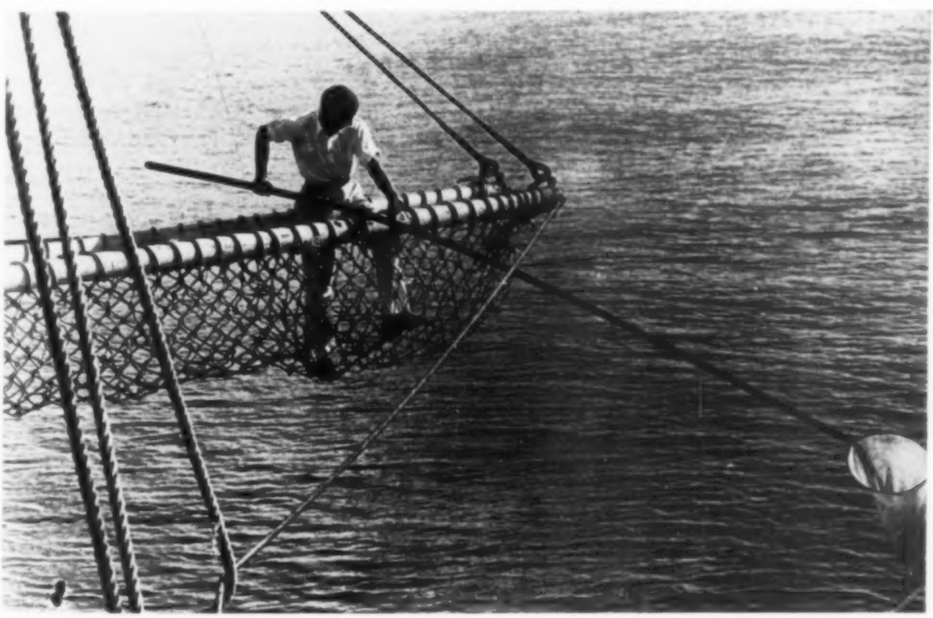
The free oxygen in sea water is derived partly from the atmosphere by absorption at the surface and partly from the photosynthetic activities of plants. The photosynthetic zone, as we have seen, is a superficial stratum some hundred of meters, more or less, in depth, but it does not follow that the plants throughout all the depths at which they may live are *net* contributors to the supply available for animals. In the deeper zones, inhabited by plants, they may consume as much or more oxygen than they produce, so that the net contribution is nil or a minus quantity. The level at which oxygen consumed and oxygen produced are in balance is called the "compensation point"; in the Gulf of Maine in June, 1934, this was at 24–30 meters.[16]

Carbon dioxide is soluble in sea water in about fifty times the proportion in which it is found in the atmosphere, but even that is a very small proportion: approximately 1.6 per cent. by weight in sea water as compared with 0.03 per cent. in atmosphere. Carbon dioxide is also present in sea water in "bound" and "half-bound" condition—in combination with minerals as carbonates and bicarbonates. "There is usually about 50 cc. of carbonic acid in one liter of sea water (as compared with 5–10 of oxygen), but of this only a few tenths of a cubic centimeter is free gas in solution" (Murray and Hjort). Carbon dioxide is certainly not consumed by green plants below some 1,000 meters, and doubtless rarely at that depth, although it must there be produced in quantity both by the respiration of animals and the decomposition of organic material. What then becomes of that part of it which may not enter into chemical combination with dissolved min-

[16] Clarke and Oster, 1934, p. 71.

erals? Are the vertical movements of water sufficient to maintain the proper equilibrium of dissolved gases in the depths?

Since the solubility of gases in water varies inversely with the temperature, the cold waters of the Arctic are much richer than tropical waters, in both dissolved CO_2 necessary for photosynthesis and dissolved oxygen necessary for the respiration of animals. Cold waters, being heavier than warmer waters of like salinity, tend to seek the bottom, and abyssal waters of all oceans are presumed to be derived in considerable part from the polar regions, particularly from the Antarctic, and to have been originally especially rich in oxygen. Surface waters are generally supersaturated. Deep waters might be supposed to be generally poor in oxygen, since the dissolved gas is used both in the respiration of abyssal animals and in the decomposition of organic materials which have settled to the bottom from the waters above and also because, in the absence of photosynthesis resulting from the lack of light, no oxygen is liberated there. Mixing (overturn) occurs in high latitudes, as we have seen, and especially in or at the end of winter when the colder heavier waters of the surface laden with oxygen sink to a lower level to replace the somewhat lighter waters which rise to the top to become reoxygenated. Nevertheless, the actual conditions do not conform to a rule that may be simply stated. Bottom waters, especially in the Atlantic, where they may be 75 per cent. saturated, may contain more oxygen than layers far above them. Seiwell (1937) observes that the minimum concentration of oxygen in the western North Atlantic is generally between depths of 200 and 900 meters, with values ranging from 1.7 to more than 5.0 cc per liter. Vaughan says that there is in the eastern Pacific, usually between 600 and 1,200 meters, a layer where



THE BIOLOGIST, MR. SEIWELL

MAKES A SURFACE DIP FROM THE BOOM WALK ON THE "CARNEGIE." COURTESY OF THE CARNEGIE INSTITUTION OF WASHINGTON.

Photo by Coit Coker.

ATTACHING A METER NET TO THE TOWING CABLE FOR COLLECTING PLANKTON

ON THE "ASTERIAS" OF THE WOODS HOLE OCEANOGRAPHIC INSTITUTION. SEVERAL SUCH NETS MAY BE USED AT DIFFERENT DEPTHS ON THE SAME CABLE.

the water is only 5 per cent. saturated with oxygen, while below that the maximum saturation may range between 30 per cent. and 40 per cent.

The conditions of life of all animals and plants in the sea and in other waters, as compared with those of terrestrial organisms, are marked by this important distinction—that the requisite gaseous oxygen occurs in relatively extreme degree of dilution. A liter of air contains 25 or more times the amount of oxygen that can be dissolved in a liter of sea water. Free carbon dioxide, on the other hand, may occur in approximately the same volume in sea water as in the atmosphere.

CONDITIONS OF LIFE IN THE DEPTHS

In the depths of the sea there is, of course, a great stillness—no wave movements, no tides, no vibrations; even the slow drifts, horizontal or vertical, traceable to conditions of wind, temperature or salinity elsewhere, as well as to the rotation of the earth and extra-terrestrial influences, can scarcely be felt.[17] The very build of some of the inhabitants of the great depths would render them quite incapable of taking care of themselves at the surface: the greatest living crustacean, *Kaempfferia kaempfferi*, five meters in expanse of limbs, would be utterly helpless in wave-disturbed waters. The abyssal regions may then be thought of as regions of utter darkness, almost absolute stillness, tremendous pressure, very low temperature and limited supply of free oxygen; and, of these, the amazing pressure is of perhaps the least biological significance. Such are the conditions under which the denizens of the deep may appropriately be said to "pursue the even tenor of their ways." There can be comparatively little local or seasonal variation in the conditions of existence. From east to west and north to south, under the tropics or beneath the Arctic and Antarctic circles, from June to December and from December to June, there is no change in the conditions of light, because there is no light beyond such momentary flashes as may be produced by the light organs of abyssal animals; there are no pronounced differences in temperature, no storms and virtually no perceptible currents. From place to place there may indeed be con-

[17] So, at least, we picture provisionally the conditions that no one can directly observe. Future knowledge of deep tidal and turbulence phenomena may necessitate some slight retouching of the picture.

siderable differences in pressure, in character of bottom and in food supply, but in most regions such differences, other than those in pressure, would presumably be encountered very gradually and at the cost of considerable travel.

It is not remarkable that the idea once held sway that the floor of the sea beyond the Continental Shelf was without life, a great desert, an azoic area: in this pitch-blackness, whence could come the supply of free oxygen to support animal life? In temperate and Arctic regions, wherever the surface waters may at times be brought to a temperature at which it is heavier than the waters below, they will, of course, sink toward the bottom to be replaced at the surface by lighter waters from the depths, and so, by this "overturn," the oxygen supply of abyssal waters of the region is renewed; but, over a great part of the Atlantic, Pacific and Indian Oceans, such a condition can not occur. Animals yet thrive at the bottom, presumably utilizing oxygen brought by the slow drifts of cold and richly oxygenated waters from polar regions. Probably the abyssal animals are not very abundant and lead slow lives, involving a minimum oxygen demand.

ORGANIC LIFE IN THE SEA

The Requirements of Life

In a general way the necessities of life are the same in the sea as on land: water, sunlight, heat, oxygen, carbon dioxide, food (in the form of the building materials of protoplasm and the fuel to supply energy), protection from enemies and, we might add among the necessities, enemies themselves or some means of keeping a particular population in equilibrium with its food supply. Our previous discussion has dealt adequately enough for the present purposes with the occurrence and distribution of all these requirements except the last three—food, protection and enemies.

Considering the last of these three first, the enemies of a species may generally be accounted useful to the species; since, without some control upon the increase of a population, such as is afforded by its predators, multiplication in numbers must inevitably outrun the food supply and lead to starvation. At any rate we know nothing of the existence of organisms without effective enemies and parasites. On the other hand, protection or refuge from enemies is equally essential—both for the prey and for the enemy. The predators may serve a useful purpose to themselves and to their prey as they keep the multiplication of the prey within bounds. But the prey must, in the interest of both parties to

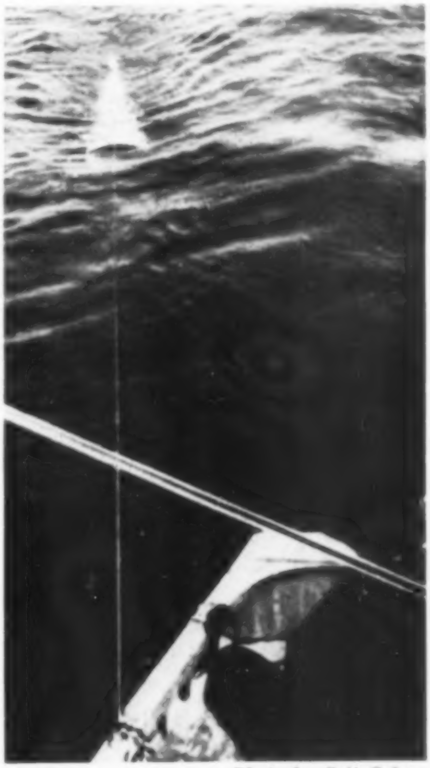


Photo by Coit Coker.

TOWING A SURFACE NET FOR PLANKTON

FROM THE "ASTERIAS" OF THE WOODS HOLE OCEANOGRAPHIC INSTITUTION.

HAULING IN THE PLANKTON NET ON THE "CARNEGIE"
COURTESY OF THE CARNEGIE INSTITUTION OF WASHINGTON.

the contract, have some means of regulating the extent of the depredations made upon them.

On land, in fresh water and in coastal waters, there exists for animal life what is called shelter or refuge in the thickets of vegetation which play a significant part in preserving some sort of balance between the warring members of the community—in short, between consumption and supply. In the picture that has been given of the open sea, that is to say, of what is by far the greater part of the oceans, we must have been impressed with the entire lack of refuge. Where the vegetation is composed exclusively of plant bodies of microscopic size scattered and free floating—in this sort of diffuse and open pasture there is no place of hiding. Survival or death for plants and for the animals of feeble powers of locomotion, which includes the vast majority of plankton animals, depends upon the accidents of the presence and state of hunger of the potential consumer. Transparency of body is a chief resort for concealment, and prolificness in production the strongest hope of survival of the species. Transparency means high water content and, as Ostwald remarked long ago, no organisms are so rich in water as the inhabitants of the open waters of lake or ocean.

Wherever shelter occurs in the sea it is availed of. Clams, worms and crustacea burrow in the bottom, and even in rock, or find concealment among the shells of the bottom. The discarded shells of conchs become the houses of hermit crabs. Oyster beds and thickets of eelgrass harbor a rich and varied population of small plants and animals. The sargassum weed, which occurs in large floating gardens, offers one of the rare refuges of the ocean proper, and the extensive masses of weed are true zoological gardens: they afford shelter to what, to the uninitiated, is an astonishing community of fish, mollusks, crustacea and other animals which manifest the most bizarre forms in correspondence with their peculiar habitat. Still other animals find refuge within the bells of jellyfishes. Many other instances of the intrusion of animals into every available form of refuge could be cited; but all these will account for but a small part of the life in the sea. The ocean generally is a place without tangible refuge. We know little, of course, of the conditions of life on the bottom, but, above the bottom, protection for the small organisms that predominate must depend upon

translucency or other means of making their bodies inconspicuous or upon the ability to live in the darkness below the upper illuminated zones. We know of no considerable habitat on land where want of refuge prevails in a way at all comparable to that which marks the greater part of the surface of the earth, occupied as it is by the open sea.

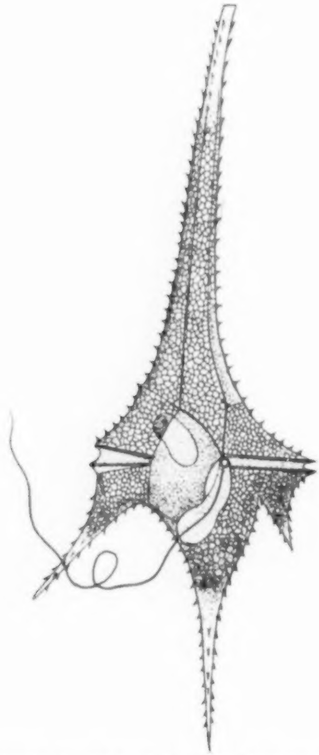
Finally, as regards food, we have in the sea, as on land, a great organic cycle in which organisms feed and sooner or later serve as food. The food cycle might be said to begin with the utilization of inorganic materials by green or yellow or brown plants, to run through the chain of vegetarian animals and carnivores, to continue with the reduction of organic wastes by bacteria of decomposition, and thus to begin again.

Before passing to a consideration of the kinds of plants and animals that live in the sea, we might recall Haeckel's classification of aquatic organic life by mode of living, as Benthos, Nekton and Plankton, the last being Hensen's terms. Benthonic animals or plants are those that live in close association with the bottom or with relatively fixed objects: worms that burrow, crabs that crawl, snails that creep over plant stems, barnacles that are attached to any available object, living or dead, etc. The nekton comprises animals that rove freely in the water, having no necessary connection with the bottom: fish, squid, whales, etc. The plankton is comprised of the plants and animals, generally small and with bodies scarcely heavier than sea water, that have limited powers of locomotion and that are therefore carried about by the currents. The classification is not all-inclusive, and there is no sharp line between the several groups. Nevertheless, it has some convenience, and the term plankton, at least, has become practically indispensable.

As we have suggested on an earlier page, the seas, in spite of their continuity and relative uniformity in proportions of the several mineral salts in solution, do not constitute a single habitat, and the life in the sea does not compose a single community. This applies not only to the animals and plants that live along the shores of continents and islands where the fauna and flora is richest and where the differences in habitats are observable by any one, but also to the plankton or drifting organisms as well. As knowledge of the plankton has progressed, with qualitative and quantitative studies in various parts of the ocean, it is now even surprising that some serious students once conceived of a uniform distribution

A HEAVY CATCH IN THE LOWER PART OF THE PLANKTON NET

FAR MORE THAN THE "BUCKET" CAN HOLD. PHOTO FROM THE "CARNEGIE." COURTESY OF THE CARNEGIE INSTITUTION OF WASHINGTON.



A DINOFLAGELLATE PROTOZOAN OR PROTOPHYTE, *CERATIUM HIRUNDINELLA*
(FROM KUDO AFTER STEIN.)

of floating life in the open ocean. It is elementary knowledge now that there is great diversity in the composition of plankton, not only in different regions and at different depths, but also at different seasons and at different hours at the same place and depth and probably even in different years.[18] The conditions that lead to maxima and minima, as well as to minor fluctuations of abundance of any particular plant or animal, are complex indeed in their physical, chemical and biological aspects.

We are fundamentally wrong in our conception of the plankton, if we do not picture it as always and everywhere in process of change. At any spot changes may occur in the kinds of animals that are present and in the relative and absolute numbers of the several kinds of animals and plants. We might conceive of the sea with its drifting minute life as like a sky of great depth full of clouds of very unequal densities, clouds that rise or fall, drift from place to place, and become heavier or lighter. Perhaps in some parts of the sky, particularly those remote from the horizon, the clouds, though variable, are always thin. In other regions, the variations in density may sometimes show a decrease to extreme dilution or, again, an increase to the point of oversaturation, followed, in the case of the clouds in the sky, by precipitation, or, in the case of the plankton, by mortality—in either case by a relative clearing. Such an analogy would, however, fall far short. The clouds in the sky have a single component, water vapor, and they vary only in degree of concentration of this one thing. The plankton clouds have a few dozen of components, the proportions of which are most inconstant. We should have to go much farther, indeed, and imagine that the several distinct kinds of droplets in the clouds could multiply, could devour each other and could be individually precipitated.

PLANT LIFE IN THE SEA

Such frequent allusion has already been made to the vegetation in the sea that we may now deal very briefly with this, the greater part of the organic world: for, after all, vegetation is the broad base of the pyramid of life in the sea. The contrast to conditions on land

[18] Bigelow (1926, p. 78): "Even a cursory examination of the Zooplankton, if extended over a considerable area or through a considerable period of time, is certain to reveal wide fluctuations in abundance as well as in its qualitative composition, both from season to season and from place to place." Allen (1934, p. 172): "From this and other evidence accumulated by the Scripps Institution over a period of thirty years it appears certain that uniformity of distribution of plankton in sea water, either horizontally or vertically, is practically nonexistent in Southern California waters at any time, whatever may be the condition in some other oceanic locality."

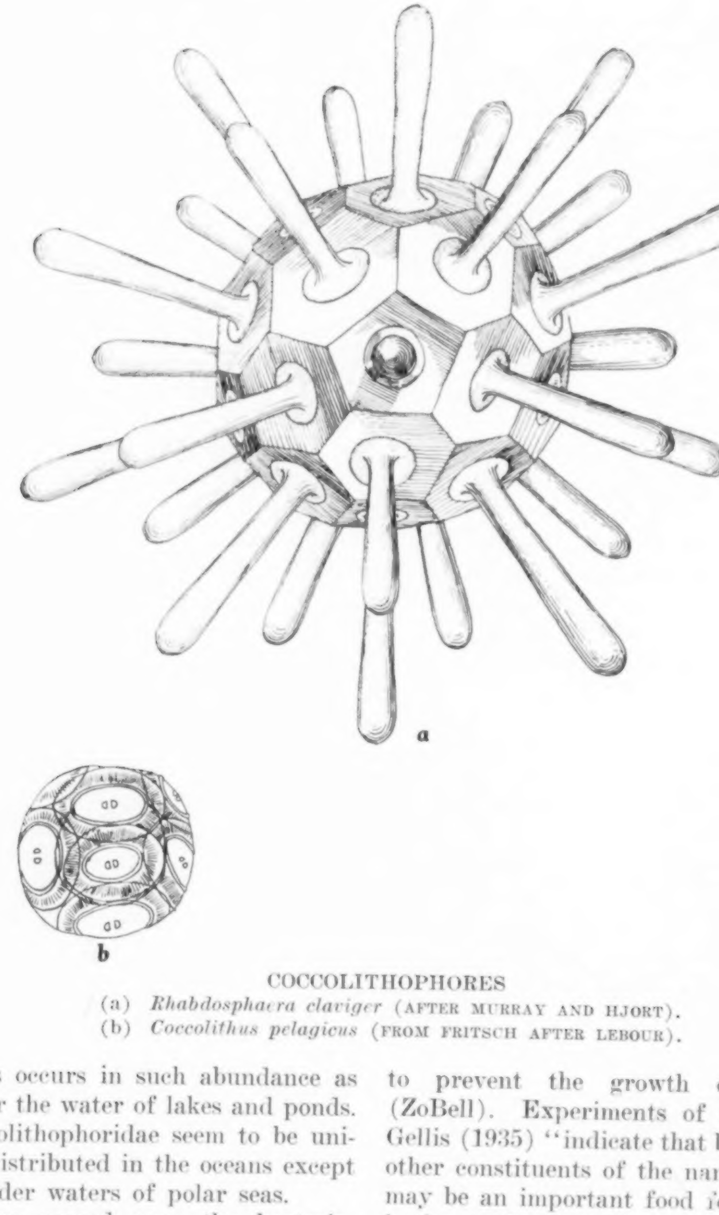
is marked. None of the higher plants occur in the ocean remote from the shores. Seed plants are totally wanting, and mosses and ferns as well. Even along the coasts the larger algae are chiefly of groups not represented on land or in fresh waters. The great group of blue-green algae, abundant in lakes and rivers, are prominent in the ocean only in waters near the mouths of large rivers or in tropical regions. The green algae, predominant in fresh waters, are sparsely represented in salt water and then chiefly where there is some admixture of fresh water. On the other hand, brown and red algae, richly present in the benthonic life of the ocean along and near the coast, are most sparingly represented in fresh waters. Brown algae, including rock weeds, sargassum and kelps, are the largest and most conspicuous of coastal marine algae: the more delicate red algae on the bottom extend farther out into the sea, living not only in harbors and along the shores but also in the deeper waters of the Continental Shelf beyond the depths of penetration of the shorter rays of sunlight necessary for the growth of true green plants. The red algae are, therefore, presumably of special significance as "producers" or photosynthetic agents on the Continental Shelf.

The brown seaweed, Sargassum, is the only large seaweed that finds a prominent place in the high seas. Breaking loose from the rocks to which it is attached along certain shores, it drifts in the currents, multiplying vegetatively as it goes, and accumulates in the great eddy in the Atlantic Ocean known as the Sargasso Sea. Here, as it grows and before it dies to sink and decompose, it forms an extensive shelter for a remarkable special community of animals, many of which can live nowhere else than in the clumps of Sargassum.

The off-shore plant life, barring the floating Sargassum, is, as we have repeatedly observed, of extreme simplicity of form. Even the relatively simple filamentous forms so characteristic of all sorts of fresh water are missing. Conditions in the sea have not favored cell aggregations and the associated specialization in form and development of larger bodies.

There is, indeed, a marked paucity of green algae. The Chlorophyceae are represented in the open sea chiefly by a single species, *Halosphaera viridis*, which, although minute in size, has yet caught the eye of Mediterranean fishermen who long ago named it "Punti verdi" (green points). On the other hand, the unicellular algae called diatoms, with siliceous shells, and the dinoflagellates (some plant-like, some animal-like), occur abundantly in both fresh and salt water. But, except for bottom-living diatoms, it is in the sea that the plants of both of these groups attain their fullest flower. Great areas may be discolored by them. The conspicuous "red seas" that arrest the eyes of voyagers and are many square miles in extent are sometimes at least attributable to immense swarms of dinoflagellates. Again, the surface waters for miles and miles may be discolored and actually "soupy" with diatoms. All the plankton algae are, of course, restricted to the upper few hundred meters except as their falling bodies may invade the regions of darkness below.

Still smaller are the Coccolithophoridae which are said to constitute a large proportion of the marine planktons, but which pass through the finest silk nets and must be sought by centrifuging. The name means "bearers of coccoliths," for the minute bodies are protected by calcareous plates or spicules of the order of size of bacteria and long known as a substantial component of deep sea calcareous deposits, especially the Globigerina Ooze. These algae (or protozoa) are of the group of yellow flagellates called Chrysomonads, to which belong also Dinobryon, a fresh-water algae that



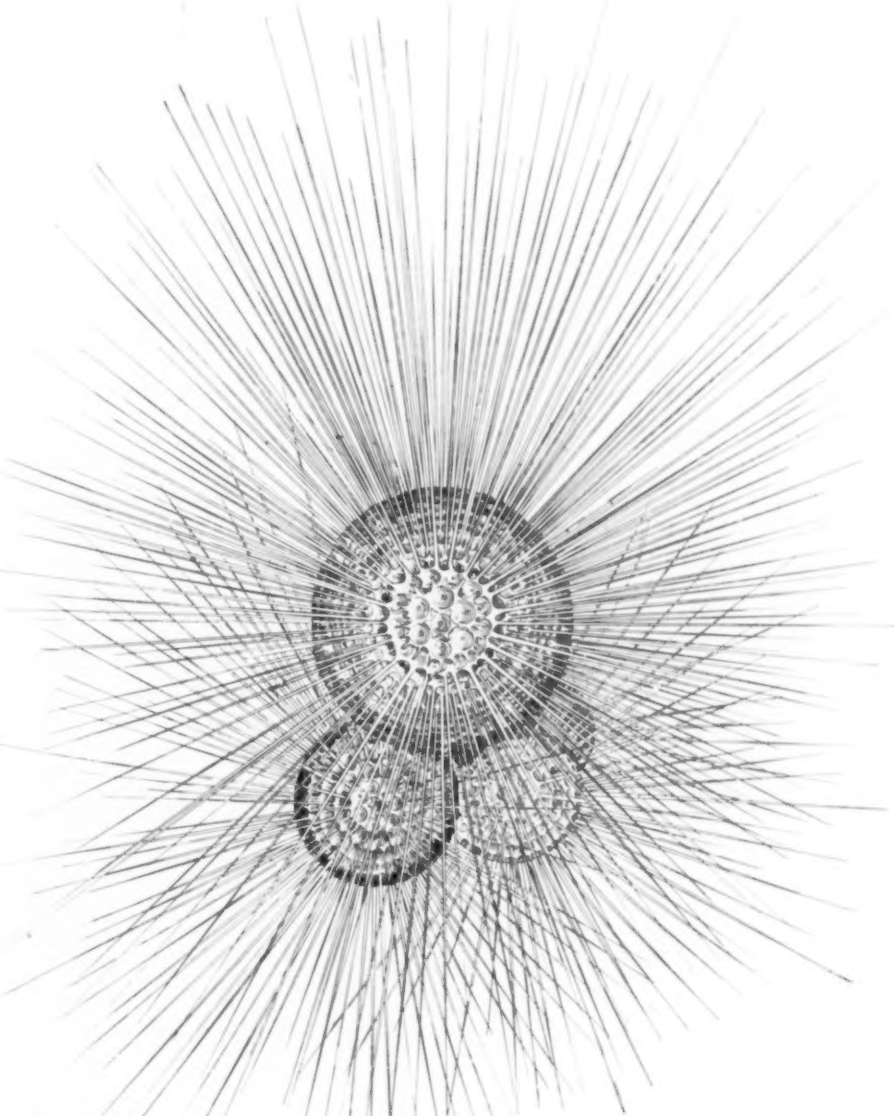
COCCOLITHOPHORES
(a) *Rhabdosphaera claviger* (AFTER MURRAY AND HJORT).
(b) *Coccolithus pelagicus* (FROM FRITSCH AFTER LEBOUR).

sometimes occurs in such abundance as to discolor the water of lakes and ponds. The Coccolithophoridae seem to be universally distributed in the oceans except in the colder waters of polar seas.

We have passed over the bacteria, which, according to some accounts at least, are not notably abundant in the sea, although as yet comparatively little is known of the bacteria of the bottom. There is nothing in the conditions of temperature and pressure in the bottom to prevent the growth of bacteria (ZoBell). Experiments of Clarke and Gellis (1935) "indicate that bacteria and other constituents of the nannoplankton may be an important food for copepods in the sea." Bacteria may serve to some extent as synthetic agents in regions of the sea where green plants can not function, but we have too little information concerning the significance of bacteria in the ocean.

Although the higher plants are com-

pletely wanting in the open sea, we should refer to a seed-plant that is commonly of considerable significance in coastal waters and perhaps beyond. The common "eelgrass," Zostera, a flowering plant of the pond-weed family, occurs on almost all ocean shores where wave action is not severe. Its abundance and general distribution is indicated by the windrows of it seen on beaches of harbor and ocean. As the annual crops of eelgrass die and are broken to pieces, the fine detritus to



THE PROTOZOAN, *GLOBIGERINA BULLOIDES* D'ORBIGNY
(AFTER MURRAY AND HJORT.)

which it is ultimately reduced may be carried well out to sea to constitute a basic food supply for many kinds of animals. Some biologists have indeed attached greater importance to the detritus formed from eelgrass grown in shallow waters than to the phytoplankton multiplying in the offshore waters as the support of animal life in the ocean. A remarkable phenomenon and one not yet adequately accounted for, has been the recent and comparatively sudden disappearance of eelgrass on both sides of the Atlantic and on some Pacific shores, apparently as the result of or with the accompaniment of some sort of disease. Apparently this disaster to eelgrass and, of course, to many of the animals associated with it, is not entirely without precedent, but why does the disease appear so suddenly and in such wide-spread fashion?

In summary as regards plant life in the sea, those species of plants that are visible to the eye play a minor part in the "metabolism of the sea," and emphasis must be placed on the minute species. "This," says Brooks (1893) "is the fundamental conception of marine biology: The basis of all the life in the modern ocean is to be sought in the microorganisms of the surface."

ANIMAL LIFE IN THE SEA

Comparison of Oceanic and Other Faunas

With such a contrast as prevails between the forms and sizes of plants in the ocean and on land, respectively, it is to be expected that there would be a corresponding contrast in respect to the sizes of the primary consumers of plants. Brooks long ago remarked on the apparent scarcity of vegetarian animals in the ocean. All the familiar animals are carnivorous; there are no great groups in the sea corresponding to the order of rodents on land or to the plant-eating birds and insects, to say nothing of the larger browsing and grazing animals such as deer, horses, cows, elephants, etc.; yet, according to the principle of the pyramid of numbers, the vegetarian animals must greatly outnumber the carnivores. These are actually present in enormous numbers, but individually they are quite small. Some are protozoa, but the chief plant consumers of the sea, and the main support of the carnivorous animals, are generally accounted to be the smaller crustacea and, among these, principally the copepods.

> We have already seen that the eucopepods are the chief intermediaries between the microorganisms of the ocean and the larger and higher marine animals; that they prey upon the protophytes and protozoa, and in their turn supply either directly or indirectly most of the food for the large inhabitants of the water; that most pelagic larvae feed upon them; that they are the food of the great pelagic banks of pteropods and heteropods (mollusks), of many coelenterates, of the young of most fishes, and of some of the most abundant and important adult fishes, like the herring, and that the sea birds, the cetacea, and in fact almost all the larger pelagic animals, prey upon animals which in their turn prey upon copepods.[19]

There are other distinctive features of the marine communities as a whole. Comparison of fresh-water and marine plankton reveals a far greater variety of animals in the latter. In the first place, a most important element of the marine plankton is what is called *meroplankton*, comprising the larvae of organisms that spend only part of their lives in the plankton. Such are the young of starfishes and sea urchins, of worms, mollusks, crabs and sedentary ascidians. On the other hand, animal meroplankters constitute a very insignificant part of the communities of fresh-water plankton. There are also in the sea a great number of *holoplankters* (animals living exclusively in the plankton) of groups not represented in the plankton of fresh waters. Among such are free-swimming

[19] Brooks, p. 161.

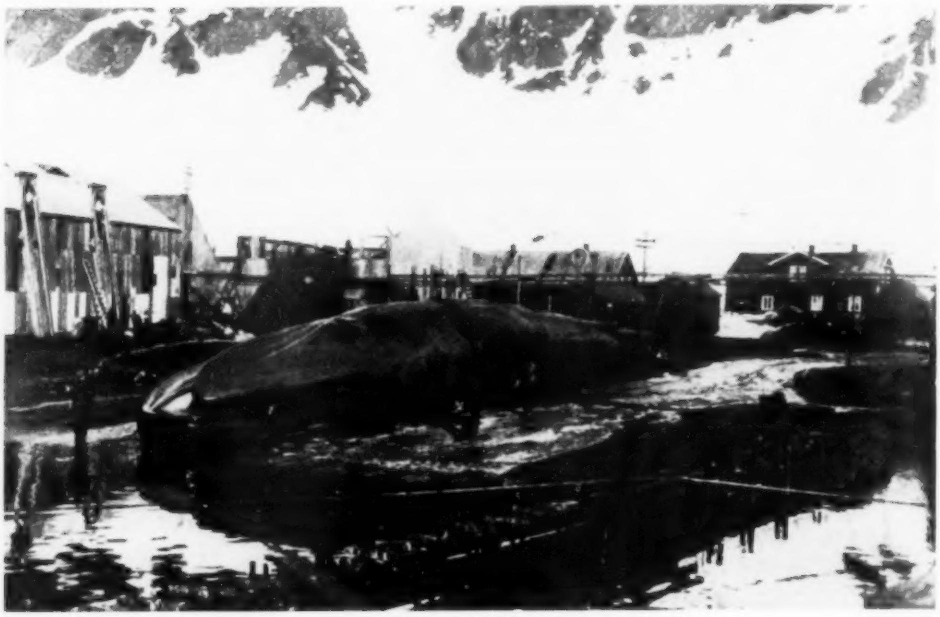
mollusks (pteropods and heteropods), worms and free-living tunicates. The paucity in variety, not in quantity, of fresh-water plankton animals—protozoa, rotifers, crustacea of three groups, and little else—offers a striking contrast.

A brief and very general review of the distribution of animals of the several phyla, with respect to fresh water, the sea and the land may be illuminating. To begin with the simplest forms, no sharp distinction can be made between the protozoa and the flagellated protophytes such as the coccolithophores and dinoflagellates to which references have previously been made. With respect to protozoa proper, the casual collector will undoubtedly make acquaintance with a much greater diversity of types of protozoa in fresh water, but the unicellular animals play an equal and probably a much greater part in the bionomics of the sea than in that of fresh waters. The extensive areas of Globigerina Ooze, covering more than half the floor of the Atlantic, and the less extensive but still significant areas of radiolarian ooze testify to the vast abundance of both Foraminifera and Radiolaria, groups that are scarcely represented, the Radiolaria not at all, in fresh waters. Again, one could hardly encounter in fresh waters any phenomenon comparable to the occasional enormous populations of the cystoflagellates, ***Pyrocystis noctiluca*** and ***Noctiluca miliaris***, flagellate protozoa of very large size, up to 1 mm in diameter for Noctiluca, and characterized by the capacity for luminescence. In certain coastal waters, as at Beaufort, N. C., Noctiluca may at times occur with such density of population that any moving body in the water is brilliantly outlined in light by the flashes of the protozoa with which all parts of its body are making continuous contact. More impressive testimony to the capacity of some organisms for multiplication or for concentration in the sea under conditions not fully understood is that of Allen (1937), who found *Noctiluca scintillans* in a concentration of 3 million to a liter in sea water as *dipped* from the surface in the Gulf of California. Since this well-named "Scintillating Night Light" is macroscopic rather than microscopic in size (it may attain a diameter of one millimeter) 3 million of them in one million cubic millimeters would leave little room for water. The cystoflagellates are almost entirely marine, but some other groups of flagellates, the ciliates and tentaculates, are more numerous in fresh water. Nevertheless,

GIANT OSTRACOD
Gigantocypris agassizii G. W. MÜLLER.
(FROM MURRAY AND HJORT AFTER MÜLLER.)

Clemens (1935) has found great patches of water near Nanaimo, B. C., colored "crimson red" with a "pure culture" of a ciliate protozoan, *Mesodinium rubrum* Lohmann.

The sponges and the coelenterates each comprise a great number of species with notable diversity of form and habit, and nearly all species of both groups are found only in the sea. Likewise, the polyzoa or moss animalcules are mostly marine; only a few species of each of these phyla have invaded fresh water. Nemerteans, or ribbon worms (with an excep-



BLUE WHALE ON FLENSING PLATFORM
AT WHALING STATION IN SOUTH SEAS. FROM "DISCOVERY" REPORTS.

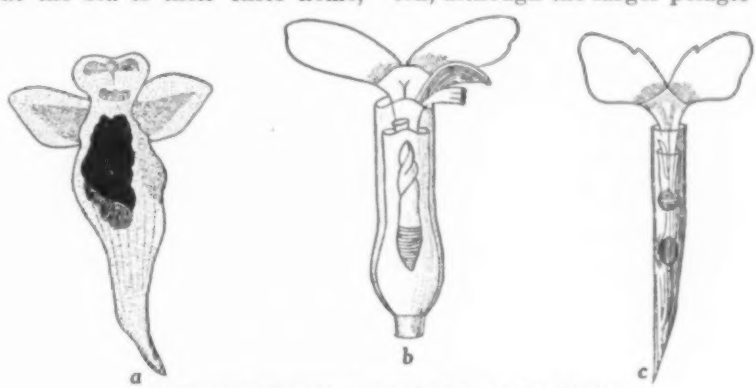
tion or two), Echinoderms (starfishes, etc.) and Brachiopods are exclusively marine while, on the other hand, rotifers, with a few exceptions, and Gastrotrichs are restricted to fresh waters. Flat worms and round worms, respectively, are much more generally distributed, occurring in salt and fresh waters, and as parasites in fresh-water and terrestrial animals. Among the Annelids there are two small classes that are exclusively marine; a third class, the Chaetopods, which embraces the worms proper, are widely represented both in sea and in fresh water, but in the main those of the sea belong to one subclass and those of fresh water to another; the leeches, constituting the fourth class, are almost exclusively inhabitants of fresh water, although a few are marine or terrestrial.

The mollusks embrace two classes that are exclusively marine, the Scaphopods (tooth shells) and the Cephalopods (squid, octopus, nautilus); those of a third class, the Pelecypods or bivalves, occur broadly in fresh waters and in all seas, but doubtless the greater number of species are marine. The Gastropods, including snails and conchs, are also more abundantly represented in salt than in fresh water, but two very distinct types of snails have invaded the fresh waters and there developed a considerable diversity of species. One of these groups, comprising the pulmonate snails, has entered the fresh waters indirectly, by way of the land, and its members are but imperfectly adapted to life in water. The most prominent point of contrast between the molluscan faunas of fresh waters and oceans is found in the entire lack in the former of the free-swimming mollusks that constitute so significant a part of the oceanic fauna. Reference is made to the Heteropods and Pteropods (among the gastropods), the latter as "flying snails" or "delicate shield-shaped shells driven along by a pair of flapping fleshy wings"

(Beebe), frequently so extraordinarily numerous in the plankton as to merit the name of "whale-feed"—and to the Cephalopods, represented by the great schools of squid, the floating argonauts and other well-known types. All fresh-water mollusks, in contrast, are benthonic—creepers, clingers or burrowers.

The several classes of arthropods divide themselves conveniently into two groups, comprising, respectively, those that breathe by means of gills, the Crustacea, and those that have the tracheal system of respiration, chiefly myriapods, insects and arachnids. The several classes of the tracheates are, of course, primarily terrestrial, but a number of insects and arachnids have invaded the fresh waters and a *very few* have returned to the ocean. The Crustacea are extensively represented both in the sea and in fresh waters, but the barnacles are exclusively marine, and the ostracods and the larger Crustacea (crabs, lobsters, shrimps, etc.) chiefly so, with few genera in fresh waters. The Branchiopods (fairy-shrimp, cladocera, etc.), on the other hand, are principally inhabitants of fresh waters. The copepods are much more equitably distributed between the two kinds of waters, but the sea is their chief home, and there they are paramount among the small animals. "It is an undoubted fact," says Russell (1934, p. 2025) "that the Copepods are the most numerous components of the animal plankton community." Neither on land nor in fresh water can there be found a single small group so generally dominant as are the four or five species of copepods that account for such a large part of the oceanic plankton. For a comparable condition we should perhaps have to take a single lake or a single habitat on land offering uniformity in chemical conditions.

We have to pass over the diversity of larger crustacea which occur in profusion in the ocean but are scantily represented by crayfish, amphipods, isopods and a few shrimp in fresh waters or by isopods and crabs of very limited distribution on land. Most of the larger crustacea are benthonic, but their larvae may be very prominent components of the plankton, and some species are pelagic at all stages. I have seen great areas of the Pacific Ocean, off the coast of Peru, blood-red with the shrimp, *Munida cokeri* Rathbun, about two inches in length. Unlike the mollusks, the free-swimming crustacea are well represented in fresh-water plankton, although the larger pelagic crustacea



FREE SWIMMING PTEROPOD MOLLUSKS
(a) *Clione limacina* PHIPPS.
(b) *Cuvierina columnella* RANG.
(c) *Creseis virgula* RANG.
("A" FROM MURRAY AND HJORT, AFTER VANHÖFFEN; "B" AND "C" FROM CAMBRIDGE NATURAL HISTORY AFTER SOULEYET.)

have no counterparts in the limnetic communities.

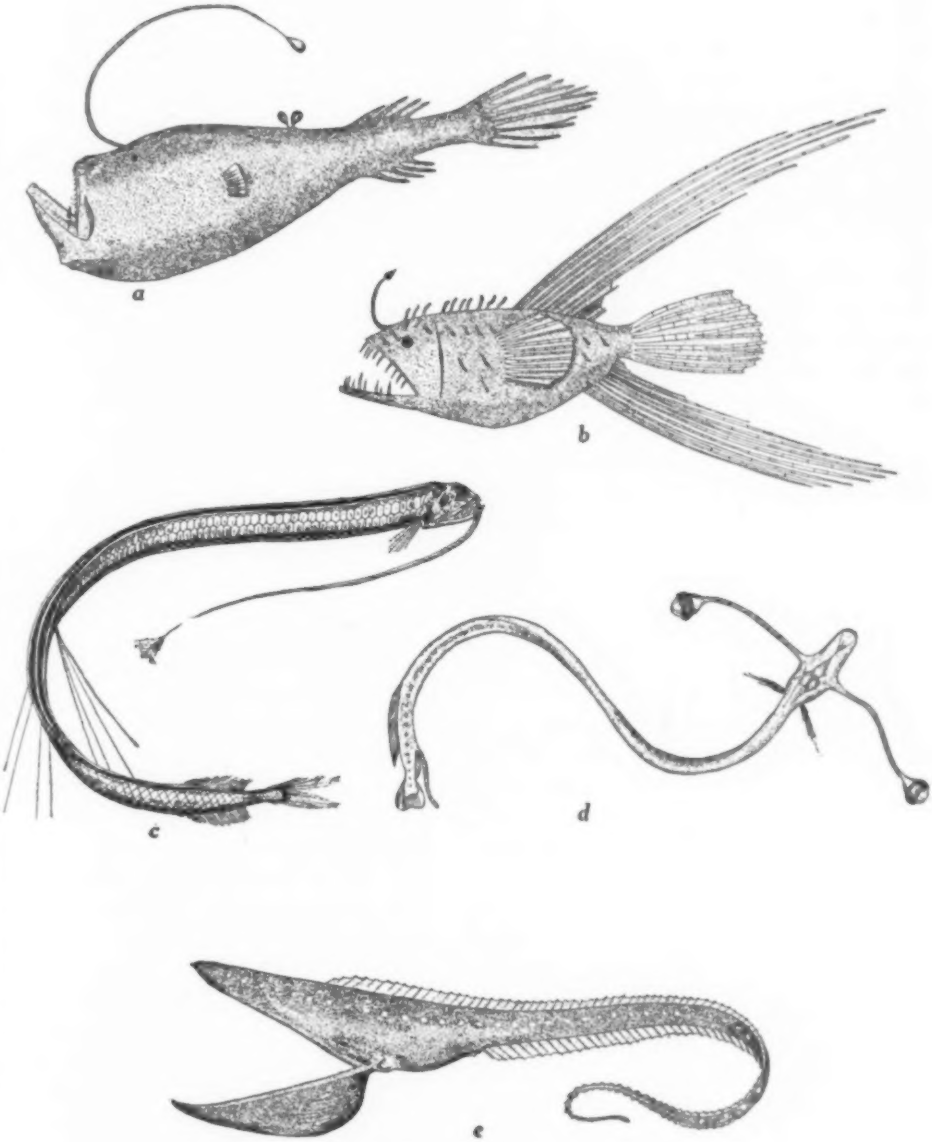
When we come to the Chordates, we find first a group of subphyla including primitive or degenerate types—Balanoglossus, the Amphioxus and the Tunicates—which are restricted to the sea, and another subphylum that comprises the six or seven classes of Vertebrates. The lowest of these classes, the Cyclostomes, are doubtless primarily of marine habit, but some species ascend the rivers and one or two remain in fresh water all the time. The fishes are, of course, widely distributed in fresh and salt water, but within this class the lower groups, the Elasmobranchs and Holocephs, are exclusively marine. There are, on the other hand, some small subclasses, the Dipnoi and the Crossopterygians, that are restricted to fresh water. The next higher class, the Amphibia, bridges the gap between land and water, but, strangely enough, is entirely unrepresented in the sea. The remaining three classes, reptiles, birds and mammals, are all terrestrial except in so far as a few species of each class have become secondarily adapted to life in water, salt or fresh.

Allusion at least should be made to animals that constitute links between land and fresh water and the ocean. Such are the seals, sea lions and many birds of aquatic or semi-aquatic habit, whose lives are divided between sea and land or atmosphere. There are also anadromous fishes, such as the shad and salmon, which feed and grow to maturity in the sea but ascend into fresh water for purposes of propagation and the location of nurseries for their young; and, on the other side, the catadromous eels which come to maturity during a period of twenty years or less in fresh water, but migrate far out into the depths of the sea to deposit eggs which develop into translucent larvae that will rise toward the surface and, in the course of a couple of years, wend their way back into the fresh waters of the continent from which their parents emigrated. A few fish are amphibious, passing freely from sea to land and back again.

From this brief review we glean one thought at least: that the diversity in basic types of living animals is much greater in the ocean than in fresh water or on land, but that, on the other hand, the number of terrestrial species is much greater owing entirely to the remarkable evolutionary success of the tracheate types—insects and arachnids. Furthermore, the more highly specialized and efficient animals have developed without the sea: fishes represent the highest form of marine life—by the systematic zoologists' system of grading. The number of species of all animals is smaller within the sea than without, but there is in the ocean a predominance of the more primitive types of animals and of those types that constitute possible links between the several phyla. In a way we may look upon the seas as representing a living museum of biological antiquities, or, it might better be said, as comprising the chief repository of the early archives of our family history.

Richness of Life in the Ocean

It is too early yet to make any strict appraisal of the quantity of life in the sea. As has been said, Krogh regards the sea as less productive than the land. Generally speaking, coastal regions and the Continental Shelf are probably more richly inhabited than the remote regions of the bottom of the sea, but, so far as we now know, there are no completely azoic depths. Similarly, as regards plankton, there appear to be no azoic levels, free-swimming organisms being encountered from the surface to the greatest depths explored. In November, 1934, Beebe descended in his bathysphere to a depth of more than 800 meters (2,500 to



OCEANIC FISHES

(a) *Mancalias shufeldtii* GILL.
(b) *Caulophryne setosus* GOODE AND BEAN.
(c) *Macrostomias longibarbatus* BRAUER.
(d) *Stylophthalmus sp.* BRAUER (young).
(e) *Gastrostomus bairdii* GILL AND RYDER.
(“C” AND “D” AFTER CHUN; OTHERS AFTER GOODE AND BEAN.)

3,000 feet). He said: "The remarkable abundance of animal life that came within our exceedingly limited visual area at almost all depths was wholly unexpected" (Beebe, 1934). Some organisms may be restricted to particular levels and even incapable of maintaining life at other levels, while others engage in notable vertical migrations, moving from great depths to superficial waters and back again. There are occasions and places where, under the influence of favorable conditions of mineral substances in solution, of other elements of food supply and of temperature, luxuriance of plant and animal life may occur to give rise to such phenomena as the great "Red Seas" of dinoflagellate protozoa (or algae) previously mentioned, or to the even more conspicuous aggregations of shrimp, of copepods or of pteropods (free-swimming mollusks) so well known to whale fishermen as pastures of "whale feed" and, accordingly, as likely indicators of the presence of the eagerly desired whalebone whales.

It is possibly correlated with the great range of movement offered by the sea as well as with the relatively high buoyancy of the saline waters that the largest of all animals, whales, occur in the sea. The whalebone whales, indeed, give us perhaps the most vivid suggestion of the capacity of plant and animal plankton of the sea to support higher animals. Feeding as they do upon the very small but macroscopic animals of the plankton, such as the copepods and pteropods which they filter out from the water, they "represent the maximum energetic efficiency attained in the ocean." Their rate of growth, says Krogh, is "unparalleled in the animal kingdom." A blue whale 7 m. long at birth and weighing 2,000 kg., he says, becomes sexually mature at 2 years, with a length of 23 m. and a weight of 60,000 to 80,000 kg. An increment in weight of body of more than 30 tons in one year manufactured from the strainings of the open sea, is indeed an impressive demonstration of intensified metabolism!

A notable phenomena of distribution is the richness of life in the cold and turbid seas of the north, when these are compared with the warm and translucent waters of the tropics where conditions of temperature and light might be expected to support the richest fauna and flora. It should be remarked, however, that waters which are geographically within the tropics but which are not tropical in conditions of temperature, such as those in the Humboldt Current off the west coast of Peru, may rival the waters of higher latitudes in luxuriance of animal and plant life. The warm and light waters of truly "tropical" regions may hold less oxygen and, remaining at the surface, be drained of their nutrient materials which are not replaced by ascending currents from the depths. "Pure blue is the color of desolation of the high seas" (Schutt, quoted by Johnstone).

Thus the colder seas are richer in life than the warmer ones; or, at the very least, the amount of life in polar seas is not less than in the tropics. We know that intense sunlight and high temperature are favorable to plant life and so these results are at first sight astonishing ones. "One stands," says Kjellman, "as before an insoluble problem when he makes a haul with a tow-net in the Arctic and obtains abundant and strong vegetation, and this at a time when the sea is covered with ice, the temperature is extremely low, and nocturnal gloom predominates even at noon."[20]

[20] Johnstone, 1908, p. 205.

THE WESTERN BIOTA

By Professor T. D. A. COCKERELL
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It is interesting to contemplate the life about us, and ask whence it came and how it came to be what it is. A complete answer to such questions is of course impossible, and were it available, it would pass our understanding. Yet the larger features of the history and some of its details may well detain us, and suggest lines of inquiry which will be fruitful of interesting results. In Colorado we find some of the earliest known traces of vertebrate animals, and through the many millions of years represented by the Mesozoic strata, gigantic dinosaurs and other strange creatures inhabited the western country. Although many fossils have been found, the record is very imperfect, as shown by the fact that several successive Cretaceous strata contain wholly diverse species, the unrecorded time interval between them having been sufficient for the evolution of an entirely new set. In those days, the country east and west of the mountains was occupied by a shallow sea, filled with life of many kinds, including fishes of gigantic size. It is probable that the origin of many of the modern groups of fishes may have been in this sea, while on the land the plants and invertebrates were already assuming what we should call a modern aspect. The attention of paleontologists has been so generally directed to mammalian evolution, which has been extraordinarily rapid, that they have not usually appreciated the vast antiquity of the groups of plants and lower animals, even many genera coming down to us from Mesozoic times.

This very ancient life, so far as represented by fossils in our region, is not closely connected with the modern biota. There has been time enough for its descendants to spread all over the earth, so far as they were able to survive and circumstances permitted, and it is doubtful whether we can ascribe any particular features of our fauna and flora to the fact that certain groups flourished in western America during Paleozoic and Mesozoic times. At what period, then, can we observe the origins of the present Rocky Mountain biota, occupying the territory where their descendants still live?

In the earlier part of the Tertiary, in the Paleocene and Eocene rocks, we find a great series of fossils, sufficiently numerous and diversified to give us a fair idea of the life of those times. It was a period of mountain-building, the dinosaurs had gone, and the mammals were rapidly developing, though still very different from those now living. But many of the plants belong to modern genera, and all of them have a modern aspect. The flora is strikingly diversified as compared with that of the Mesozoic, though the differences may no doubt be partly explained by more favorable conditions for preservation. The insects have a very modern aspect; the oldest known digger wasp, with its wings spread out and showing the pattern, would excite no surprise if collected alive in Colorado to-day. Certainly this fauna, especially as preserved in the Green River shales, contains many elements still more or less characteristic of western America, though by no means peculiar to it. Yet it also contains groups, such as the prettily marked mothlike fulgoroid Homoptera, which still abound in parts of the tropics, as India, but are unsuited to our present relatively cold climate. Lepidoptera seem to be very scarce, being represented by a couple of moths, one of them with the wings

banded just as in some living species. Dragonflies are fairly numerous, belonging to genera now extinct.

So far, it can not be said that we have positive evidence of the existence of ancestors of peculiarly western American life, unless we count such mammals as the Eohippus, considered to be a very early representative of the group including the modern horse, a group which seems to have been originally American, spreading during Tertiary times into the continents of the Eastern hemisphere. There is, however, one apparently genuine example in the genus of snails named by Pilsbry Oreohelix, or the mountain snail. Characteristic Oreohelix occur low down in the western Tertiary, and to this day the genus is dominant in the Rocky Mountain region and confined to western America. There is no reason to suppose that during the many millions of years of its existence, it ever extended into the Atlantic states, to Central or South America or into any part of the Old World. Contemporaneous with Oreohelix in the West in Eocene times were several kinds of land snails which have now disappeared from this region or are wholly extinct. Some of these are so peculiar that it has been proposed to recognize for them a distinct family, the Grangerellidae. Some important elements in the present snail fauna had perhaps not yet evolved, or it may have been a matter of chance that they were not preserved. The very distinct genus Ashmunella, with numerous species, lives in New Mexico and Arizona and has not yet been found in Colorado. Its oldest remains are Pleistocene or Holocene, yet it would occasion no surprise if it were to be found rather low down in the Tertiary.

Various writers have constructed bridges across the great oceans, in order to explain the distribution of life. It has not been sufficiently realized that the duration of life of a family of animals or plants, or even genus, and often for a species, has been ample to enable it to spread over the entire globe, supposing conditions to be favorable. Such spread might be excessively slow, yet it would suffice. It has also been argued that specific characters are not usually adaptive, because the characters by which we recognize species often appear not to affect survival. It is not necessary to show in detail that this is a mistake. Consider, for instance, the highly peculiar and very distinct Pacific Coast flora, with its accompanying fauna. Why do we not find this biota spreading eastward across the country? Obviously, because it is limited to those regions in which it can thrive. Its characters are highly adaptive, that is, suited to its normal environment.

Oceans and deserts or semi-deserts have been important limiting factors. In the Western flora we now find a long series of genera which do not belong to the region, but have come in as weeds, mostly from Europe. Some flourish exceedingly, others remain rather local or scarce. Insects show the same phenomena, and the wide distribution of the European sparrow is a case in point. These examples teach us that the great oceans are very ancient and that much time has elapsed since it was possible for the temperate biota as a whole to pass from one side of the world to the other. The circumpolar biota, which we find in our mountains and to the north, consists of species which could endure the conditions of the northern route.

The dry plains or deserts are not usually such complete barriers. It is difficult to estimate the barrier due to the dry region east of the Rocky Mountains, because about the hundredth meridian the climate changes, and it is probable that if the mountains were immediately adjacent, the Eastern biota would be hindered from spreading into them. But some recent examples prove to be exceptions to any such rule. It was supposed that the bean beetle, Epilachna, was confined to the West because of its inability

to endure other climates. But, in recent years, it has spread right across the country and has become a serious pest in the Southern States. Is it possible that it produced a physiological mutation, able to endure the more humid climate, or is it exactly the same beetle which had to wait until accidentally transported by man, probably on automobiles? Another similar case is that of the cecropia moth, so well known to every one in the Eastern states. In the Rocky Mountains we have a related species, *Samia gloveri*, strikingly different in coloration. But within the last decade or so, the cecropia has crossed the plains, north and south, in a vast army, and is now common in the Rocky Mountains. Wherever it has gone, it seems to have supplanted gloveri. In the Eastern states is a peculiar black bee, with two light spots on its tail. It is called *Melissodes bimaculata*. In quite recent years it has appeared in the country about Boulder, Colorado, and is now rather common. It is so different from the other bees of the region that it could not have been there previously, unobserved.

Northward in Saskatchewan and Alberta, the barrier is less distinct, and there is in fact a mingling of species which we have thought of as eastern and western. Furthermore, in my studies of the bees, I have found that in several cases there are closely allied but distinct species southward, represented in Alberta by forms which are not identical with either, but clearly intermediate.

There are some forms of life which are particularly instructive in regard to past conditions. Such are the fish, the mollusks, the millipedes and the earthworms. In Colorado, the two sides of the Rocky Mountains differ almost entirely in their fish fauna, not only as to species, but as to genera. The abundant small Cyprinidae or minnows of the Mississippi basin and the Eastern states generally have remained in that territory, and do not occupy the rivers and streams of the Pacific slope. This in itself is testimony to the long duration of the mountain barrier.

The mollusks, millipedes and earthworms illustrate other phenomena. Where the country has been glaciated, the native earthworms have disappeared, and there are none in Colorado, except such small forms as the Enchytraeidae. But there is a broad zone, perhaps best represented in Oregon, where the country has remained free from ice and yet moist enough to support a good earthworm fauna. Here are rather numerous endemic species of these animals. In the case of the land mollusks and the millipedes, we have numerous local species or races, isolated in different ranges which have sufficient moisture for their survival. There is evidence here of the progressive desiccation of the country, but the highly adapted desert biota proves that desert conditions existed from very remote times. The slug Anadenulus in the Cuyamaca Mountains is one of the most remarkable examples. A very distinct genus, it is represented only by a single collection made years ago by Hemphill in these mountains near San Diego. It has not been seen since, and is possibly now extinct. In Southern California, Arizona and New Mexico, there are very numerous species or races of Helicoid land snails, each confined to a very limited area. Thus it happens that in looking at a list of the snails of Southern California, one is astonished at the number of species, yet on going out into the field one is equally surprised at the scarcity of the fauna. Last spring, I visited Jacumba, on the southern border of San Diego County, right on the Mexican line. I thought I should find a snail fauna there, but although there is a creek which had brought down a great quantity of debris, not a single shell could be found. In almost any other country there would have been several or many species of small snail shells. The apparent paradox is of course explained by the

unsuitability of most of the region for snails, and the consequent isolation and differentiation of colonies in the various favorable localities. The millipedes tell just the same story.

It results from all this that the whole region is of extraordinary interest to the naturalist, who may expect to find isolated, relict species, sometimes distinct genera, at many points. This survival of ancient types is not confined to small things; it is exemplified by the species of Sequoia and the California condor, as well as various forms known to have died out in very recent geological times. Thus the Western Pleistocene, with its fossils, is of prime importance in connection with the study of existing life.

Here in Colorado we have an animal, the so-called antelope, which represents the last remnant of a remarkable and once highly diversified group, as shown in detail by Frick in a volume lately published by the American Museum of Natural History. It is widely spread, north and south, but is endemic on the Western Plains.

It is interesting to examine the various genera, and ask why some are represented by single species and others by a great multitude. Are the monotypic genera nearly always isolated remnants of a once diversified group? Why is it that certain genera are very rich in species at one time or place and poor at other times or places? Among the bees, the common genus Andrena very possibly has a thousand distinct species in the United States, and it may be that this is an under estimate. New ones are found every year, and large areas have yet to be searched for them. These bees are many of them oligotropic, that is, confined in their visits to particular types of flowers, and the diversity of the flora is connected with the diversity among the bees. But another genus, Heriades, has only a few species in North America to-day, though they were numerous in Miocene times, as shown by the fossils in the Florissant shales. They are still very numerous in the fauna of South Africa.

Work on the large genera of animals or plants is exceptionally difficult, on account of the mass of material to be dealt with, and the necessity for forming critical judgments. But it is this type of work which will help us to understand the nature and causes of the evolutionary process.

What are the prospects for work on the Western Biota in the coming years? Can we, of the older generation, contemplate our unfinished business with the assurance that a new generation, profiting from our successes, learning from our mistakes, will carry the subject to a point far beyond our present vision? We hope it may be so; we feel quite sure that, sooner or later, it will be so, but we see certain obstacles in the way. American life, whether in or out of our large institutions, is not as a rule favorable for continuous and ardent intellectual labors. There are only a few places where large collections of specimens or books can be consulted. And when the work has been done, there are few opportunities for its publication. Perhaps we should marvel that it can be published at all, when most of it is read, at the present time, by only a handful of people, and really exists primarily for posterity. Very frequently, to say the least, those doing the work have little appreciation of its broader significance, and in the nature of things it is impossible to foresee what structure of knowledge will be eventually built out of the facts now coming to light. It would doubtless help matters if there could be published, in readable form and well illustrated, a series of little manuals showing the methods of study and the broader significance of the work. Such books might interest many who would be repelled by the severely technical papers of specialists.

WHY DO INSECTS BECOME PESTS?

By Dr. E. PORTER FELT
BARTLETT TREE RESEARCH LABORATORIES

THE change from a comparatively harmless insect to a dangerous enemy of man or of material valued by him is to be expected where there is an abundance of suitable food and little or nothing in the way of natural checks.

It will help to clarify the situation if we remember that there is such a thing as the "balance of nature." There is in the world an immense number of insects and a long series of plants, each occupying a certain position and competing with other forms for the privilege of living. A great reduction in available food means a corresponding limitation in the numbers of the insect. The irregular cycles of injury of the apple tent caterpillar are due to the relative abundance of natural enemies. The wholesale killing of the caterpillars is followed by a great reduction in the numbers of the natural enemies, and these in turn increase as the caterpillars become more numerous. This is only one of many fluctuations in insect life. It illustrates what is going on all about us.

The development and prevalence of insect pests in America is an interesting story, especially as the one creature which has done the most to bring about such changes, namely, man, is the one complaining loudly because of the resultant damage to valued animals, plants and human health. It is well known that apple-tree insects are much more numerous, unless controlled, in both numbers and species in extensive apple-growing sections than elsewhere, hence the urgent need in large orchards for repeated sprayings or other repressive measures. The same thing can be seen in the extensive grape-growing sections of western New York. These hundreds of acres of vineyards offer unexampled opportunities to insects which feed upon grapes and they have not been slow to take advantage of the situation. A similar condition is developing in relation to shade trees and the insects which live upon them. In the early days of this country when communities were small and village trees few and widely scattered, there was little trouble from insect pests. The extensive plantings of elms in thickly settled areas and the numerous artificial shelters, especially belfries and open sheds, have provided ideal conditions for the wintering of elm leaf beetles near an abundance of acceptable food. It is not surprising that these insects have taken advantage of their opportunities, especially as they have been comparatively free from attacks by parasites or other natural enemies.

It is well to note in passing that a large proportion of our more serious insect pests of farm, orchard or shade trees are introductions by human agencies. Over one half of such pests have come from abroad. This has more than a passing significance, since these undesirable immigrants from other countries have by no means ceased to find their way to America. In spite of rigid quarantine restrictions of the past twenty-five years, other insects will come and take advantage of the exceptional opportunities in the western world.

Back in 1779 Hessian troops landed on Long Island, and it is the common belief that the very destructive Hessian fly was brought into the country with straw used for bedding the horses. This tiny pest found in the wheat fields of America conditions entirely to its liking and proceeded to lay a tax on American agriculture running into millions. Experience showed that certain wheats

were more resistant than others, though many farmers preferred to grow the less resistant varieties because of the larger yields and more desirable milling qualities. A hundred years after the appearance of this insect in America the more susceptible fields of wheat were occasionally blasted or destroyed. It was not until early in this century that the possibility of avoiding such catastrophic losses by seeding at the proper time was demonstrated. The insect itself is a fragile fly less than one eighth of an inch long. It travels readily with the air currents and is so prolific that millions may drift into and destroy extensive fields if the wheat plants are in a susceptible stage. The secret of success is to avoid a combination of millions of flies and tender wheat.

The fruit growers of eastern North America were much disturbed in the early 1890's when the San Jose scale was found killing orchard trees. It was so destructive that in the judgment of many progressive horticulturists apple growing as an industry was threatened. This pest was found on the Pacific Coast in 1880. It is now regarded as having originated in the Far East. Its distribution over the country was through the shipment of infested nursery stock with local distribution by both birds and wind currents. It is possible that carriage by birds was much more extended than was at first supposed. In recent years an infestation of the golden oak scale, another introduced pest, was found at South Kent, Connecticut, miles from a main thoroughfare or railroad and widely distant from recently transplanted oaks. It is probable that the young crawling scales were transported on the feet of one of the larger birds; a crow or a hawk might easily have carried the young scale insects for a number of miles. Possibly the same is true of the San Jose scale. It is interesting to note that after some twenty years in the East this wide-spread, destructive scale insect was being controlled here and there by minute parasitic insects. These were forms which previously existed in small numbers on relatively scarce, native scale insects and later took advantage of the great abundance of the San Jose scale and in time brought about what might be considered a normal balance. The scale insect throve immensely at first at the expense of its numerous tree hosts, only in turn to provide abundant provender for a, humanly speaking, beneficial parasite. Such is the way nature works.

Man has disturbed the balance of nature by planting large areas to single crops. These proved attractive to introduced pests. They also provide admirable conditions for native insects. One of the most striking cases is that of the Colorado potato beetle. Back in 1824 it was discovered feeding upon the worthless Buffalo burr or sand burr on the eastern slopes of the Rocky Mountains. Neither the insect or the plant upon which it fed was then of any importance to man. The Buffalo burr is related to the so-called Irish potato and in the late 1850's or early '60's settlers began growing the potato in that region, unthinkingly bringing to this hitherto insignificant and unimportant beetle a plant much more satisfactory as an article of diet. The insect multiplied greatly, worked eastward at the rate of about eighty-five miles a year and reached the Atlantic Coast in 1874. Here again man provided conditions favorable to the development of the pest, and in the early days of the invasion the farmer was well-nigh helpless, since he had not learned to use Paris green and was forced to depend upon hand collecting for whatever protection could be secured. This beetle, though occasionally troublesome now, is by no means the pest that it was fifty years ago. A number of natural enemies native to the invaded area have learned to prey upon the potato beetle and in many cases have reduced its numbers to such an extent that it may be

regarded as only another insect with somewhat injurious habits.

A similar story might be related of the Mexican bean beetle, which for three quarters of a century restricted its operations to the bean fields of Colorado and southward. In 1920 it appeared in northern Alabama and in 1929 was found for the first time in New England. There is evidence to support the belief that this insect was distributed to a considerable extent by wind drift. The great abundance and destructiveness of the Mexican bean beetle in the eastern states is due to the large areas devoted to beans and the comparative absence of natural enemies.

The cotton boll weevil is another insect from the Southwest. Its original home was in Mexico or central America, and one variety is known to feed on wild cotton in Arizona. It appeared in south Texas in 1892 and has gradually spread northward and eastward until it was found in every section where cotton can be grown, the annual spread of earlier years averaging about sixty miles. There is such a close limitation of the boll weevil to cotton that some years ago it was proposed to exterminate the pest in the United States by prohibiting the growing of cotton in a little over one half of the infested area for a time and then, allowing the planting of the cotton in that section, apply the same prohibitions to the remaining area, including a sufficient overlap to eliminate the possibility of spread from one area to the other. Theoretically it was possible. The boll weevil is still with us.

There are similar records in relation to insects attacking shade and forest trees. The gypsy moth, a serious and general pest of shade and forest trees in the northern United States, was brought into this country about 1868 in the hopes that a hardy cross with the silkworm could be produced and a new industry developed. It escaped, multiplied tremendously and in the early '90's the state of Massachusetts attempted to exterminate the insect. This was abandoned, and federal and state agencies joined in control work designed especially to limit spread. It was found that although the females do not fly, the young caterpillars are taken up by wind currents and carried twenty miles or more, an explanation for the occurrence of disquieting woodland infestations. The gypsy moth is also spread by the transportation of egg masses, which may be attached to a considerable variety of objects, such as building stone, lumber and even freight cars, if they happen to be standing near infested trees during the egg-laying period. It is seventy years since this insect was brought to America. It is still a serious pest in localities where no efforts are made to control it. Federal and state agencies are cooperating in an attempt to hasten biological control by the introduction and propagation of natural enemies. These beneficial forms are rendering material service, and it is possible that in time this notorious pest will become relatively innocuous.

Agencies which aid the spread of insects are of great importance. Certain beetles, especially the Colorado potato beetle and cotton boll weevil, presumably have depended to a considerable extent upon their powers of flight in view of the moderate distances covered from year to year. The Mexican bean beetle appears to have been aided considerably by wind currents, and this is undoubtedly true of small moths with a wing spread of less than half an inch, such as the apple and thorn skeletonizer and the larch case bearer, both introduced and both rapidly distributed over the country, infestations being found in remote wooded areas. It is probable that wind currents aided materially in the spread of the introduced larch sawfly, an important tamarack pest of the northern United States and also of the more recently introduced European spruce sawfly, an insect found in widely separated points in New England and northern New York in 1935. It is comparatively easy for insects to be carried long distances by air

currents. Our balloon experiments in recent years have demonstrated that drifts at moderate elevations of thirty-five or forty miles an hour are by no means uncommon and under certain conditions there may be considerably higher velocities.

Introduced insects may become of great importance because of their ability to transmit or carry plant diseases. This is well illustrated in the history of the European elm bark beetle, discovered in this country in 1909 and at that time supposed to be an important factor in killing elms at Cambridge, Massachusetts. It is believed now that the beetles were secondary enemies and that their abundance was due to the trees being in a weakened condition. This borer is unable to maintain itself in numbers on vigorous trees. It has become of great importance since the discovery of the Dutch elm disease in the northeastern states in 1933 and the subsequent finding that this beetle is the principal carrier of the elm trouble in America. The disease produces conditions most favorable to the development of the bark beetle, and the beetle is the important carrier. It is a vicious circle which can be broken by the elimination of diseased trees or the destruction of trees or parts of trees presenting conditions favorable to the breeding of the beetle. The marked strides in the control of this deadly infection in the United States have been due to systematic and thorough work by federal and state agencies toward breaking up this deadly combination.

A word as to the insects which disseminate such deadly infections as yellow fever, malaria, plague and a number of other serious affections of mankind. Both the yellow fever mosquito and the malarial mosquito must obtain their respective infections from an individual before they can convey them to another. Where there is no human reservoir these mosquitoes would be relatively harmless and here again we have man-made conditions working to his own harm. It is true that fleas become infected by plague from rats, but on the other hand rats are associates, though unwelcome, of man and there is a definite relation between the environment of man and the occurrence of plague.

It is well known that introduced insects are most likely to be much more destructive shortly after they have become well established and less injurious thirty to fifty years later. The explanation is that natural enemies which habitually prey upon related forms discover the introduced species and in time exert appreciable control. The great majority of our native species are so well controlled by adverse conditions or natural enemies of one kind or another that they are practically harmless. The Federal Government and various state agencies are attempting to hasten nature's control by searching out and establishing in this country parasites or other natural enemies which prey upon various important pests such as the gypsy moth, the Japanese beetle and the European corn-borer. Some measure of success has been obtained. Ordinarily development of biological control requires years of work. It is using bugs to control bugs. It is fascinating and logical in spite of serious limitations. The exceedingly destructive cottony cushion scale of citrus fruits was stopped in the Southwest and later in other parts of the world by the introduction of an efficient Australian lady beetle. This was a lucky strike, possibly one in a million. Usually progress in this direction must be much slower.

One must conclude that man is but one organism in a most complicated biological whole and as such can not blame his troubles entirely on Providence. It is possible for him to modify surroundings so greatly as to largely control insect pests of plants and to eliminate to a considerable extent danger from disease-carrying species.

CONSERVATION OF GAME BIRDS

By Dr. GRAEME A. CANNING
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No man should be a hunter until he is first a naturalist, for he must appreciate the problems confronting the game birds to maintain their species. Game animals should include only those whose flesh is palatable and who, by virtue of their methods of reproduction, can maintain their race. They should be only those forms whose natural wariness, speed and habits make their capture test the best of man's abilities. Among this group have been listed swimming, wading, perching and walking birds. Members of these game species were once very plentiful, but this great natural resource is gradually diminishing and a few varieties have even become extinct so that the conservation of these native game birds has become a pressing national problem.

Through greed and ignorance much of the nation's wealth has been lost, and through the inefficient cutting of forest lands, native timber areas have been destroyed. Dust storms have blown away fertile top-soil of western plains, and the air in these regions remains heavy with dust. Floods have carried off rich humus, clogging the mouth of streams and making them unfit for fish. These evidences of man's thoughtlessness have all required national programs to aid in the readjustment of nature's balances and as man has tipped the balances of the physical world against himself, so also is he now blindly destroying the wild bird life he professes to love.

Obviously in order that a species maintain itself, its rate of reproduction must equal the rate of destruction. This procreative rate is effected by: (1) the breeding areas, (2) the number of matings and young hatched during a season, (3) the numbers of pairs of birds in a territory, (4) and lastly the climatical conditions. The effectiveness of destructive factors in the maintenance of game birds are dependent upon: (1) natural powers and habits of birds which help them escape death (2) the presence of cover to which they can escape, (3) the presence of parasites to which they may be subject, (4) the prevalence of enemies from which they have to escape, such as predatory animals and the hunter, and lastly (5) unfavorable weather such as heavy snows, which will often extract an appalling toll of wild life. Some of these factors man can control; others he can only modify; while some lie beyond his power.

In the bringing about of a greater production of birds, man has two means at his disposal: (1) the establishment of natural breeding areas and (2) the artificial propagation and raising of birds. Both methods have advantages, and wherever possible they should be carried out together.

In the selection of breeding areas, particular attention should be given to natural foods and to the cover present, essential in providing location for nests and for escape. When these two factors are suitable, the game will remain in the territory and increase even when little attempt is made to check the number of natural predators. Public grounds such as parks, forests or game preserves, set apart by the state or nation, are ideally adapted for this cheapest form of game conservation and restocking.

While the above method has the advantage, much can often be accomplished by artificial propagation. This is effective, however, only with those forms which readily adapt themselves to the presence of man and which feed upon grain. Birds, such as doves, which feed their young by regurgitation are not adapted

to mass breeding, because of the obvious difficulty of mass feeding. Ducks and grouse can best be raised under "semi-natural game farming" conditions where areas are fenced off and all predators destroyed so that the young can be turned loose early and forced to find their own food without the danger of being destroyed. Under these conditions the nests can also be located and periodically robbed of the eggs, thus forcing the game bird to lay additional eggs and taking full advantage of their high productivity. The eggs removed can be incubated and the young turned loose early in life.

Artificial propagation finds its greatest use in the handling of birds such as quail, turkey and pheasants. Some idea of the high efficiency of this method is obtained when it is recalled that a pair of quail will hatch a covey of 14 or 15 birds, of which, frequently, only ten or twelve reach maturity. Under artificial, forced conditions a hen may produce an average of 60 to 70 eggs; 74 per cent. of these can be hatched and 67 per cent. of the chicks of this number raised.

As the region becomes stocked the number of pairs in a territory will increase and accelerate the return to the full game population suitable to the area. Weather conditions should always be carefully studied, since they effect the hatch and thus determine the number of birds that can be killed during the hunting season without depleting the breeding stock. Cold, severe winters will reduce the number of breeding pairs of the next spring. An excessively rainy season will be followed by a poor hatch, as floods will destroy many nests and young birds. On the other hand, excessive dryness will prevent the hatching of many eggs, for proper humidity is an important factor.

Control breeding also has the advantage of permitting matings between desirable types. However, much thought must be given to establish what is the "desirable type," for the breeder must hold constantly in mind that the game bird's color, weight and size have been evolved and established through generations of natural selection operating in accordance with the impartial law of the survival of the fit. Man should hesitate before he attempts to change any of these factors in the bird's biology. Though certain forms seem to possess characteristics more desirable than native stock, the native possesses its features as a result of selection in the region to which it is endemic.

Man need not, therefore, bother himself by attempting to increase the birds' powers to escape or to resist parasites or inclement weather, for these powers they already possess. Man can far better apply his efforts in restoring their natural habitats. Modern farming has removed their natural cover, and the barbwire fence has replaced the zigzagging rail fence behind which upland game formerly found refuge. Modern farming methods, with the removal of all natural protection, is undoubtedly one of the most important factors in the disappearance of game. A quail on the closely cut field stands out conspicuously against a bare sky-line and a widely spaced barbwire fence affords it no protection from the predatory bird or mammal. Although in many regions the numbers of hawks and native fur-bearing animals have been decreased, this reduction has been augmented by an increase of the house cat and in some regions the fox. These carnivorous animals are relentless hunters, both in and out of season, and the cat, at least, multiplies its numbers under the protection of man.

The development of the modern shotgun has added a new problem with which game birds must contend. Yet, no hunter wants to see the extinction of any of these forms. To him the whistling of the ducks' wings heralded by their chuckling or quacking is cherished music. Is

there in nature a more beautiful sight than a flock of doves swooping with the wind and sailing close to the ground, suddenly rising fifty to a hundred feet, and then tumbling and zigzagging out of range of the hunters' gun? What can be more thrilling than watching your favorite dog, backed by the others, suddenly freeze on a point? Once experienced, can man forget the tenseness of those minutes just before a whirl of wings sends the plump, brown bodies of the quail up and away to the protecting thicket at a rate of forty miles per hour? What man, having experienced these, would ever wish to eliminate them? They are sounds that stir again in him the spirit of conquest that has made him what he is. They cause his whole system to vibrate again with the life that cities and underhanded methods of civilization are tending to destroy. Through hunting, the man and the naturalist gain a new and a greater appreciation of the life they love. Human ignorance is the real destroyer of our wild game.

THE DIFFERENTIAL TIME INTERVAL FOR REMARRIAGE OF WIDOWERS

By Dr. RAY H. ABRAMS

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In the event of the death of the wife how long does the average man wait until he remarries? While there are no statistics available on this question, as far as the writer knows, nevertheless, for certain selected groups, the approximate interval between the death of the wife and the remarriage of the husband can be ascertained.

In "Who's Who in America" there is enough available data to make possible the building up of a fairly accurate picture for various selected business and professional groups. Every case in the above volume, where the date of the death of the first wife and the date of the second marriage is given, has been included in Table I, according to the various occupational groups.

The crude mode and the median show that most of the men in these selected groups who remarry do not wait very long. The average step up to the altar about two and one half years after the marital partner has died. While there are no startling differences between these groups, there are a few that select their mates in less time than that.

If the median be used, the clergy, with the exception of the scientists, get married more quickly than any of the others. One half of them are remarried within two years. This reflects the social pressure exerted upon the Protestant clergyman to secure a wife. She is a necessity in the manse and in many respects an ecclesiastical asset. In most of the denominations a wife is considered a prerequisite for the minister who is interested in establishing himself in the pastorate. Bachelors, generally speaking, are not wanted by the churches. Hence, the widowed clergyman has additional reasons for remarrying which men in most of the other professions do not have.

The scientists in the sample number 71. This, as in the case of the engineers, scarcely constitutes a large enough number to warrant framing conclusions. But if, as the arithmetic mean and the median indicate, the scientists do remarry more quickly than members of other groups how can this phenomenon be explained?

It is proverbially true that artists and writers are more given to love and romance than persons in most other voca-

TABLE I

LENGTH OF TIME ELAPSING BETWEEN DEATH OF FIRST WIFE AND REMARRIAGE OF WIDOWERS ACCORDING TO BUSINESS AND PROFESSIONAL GROUPS. BASED ON WHO'S WHO IN AMERICA, 1932–33.*

Interval (in years) between death of first wife and the second marriage	Business	Educators	Clergy	Lawyers	Public officials	Writers and artists	Engineers	Physicians and surgeons	Scientists	Total Group in "Who's Who in America"
1	27	39	45	11	13	32	16	8	13	226
2	37	51	67	28	27	32	11	23	25	322
3	46	47	35	18	19	15	11	11	10	220
4	21	26	20	15	14	17	6	6	7	141
5†	10	20	17	6	8	9	8	6	3	91
Total cases	202	246	230	111	109	146	67	71	71	1,333
Averages in Years:										
Crude Mode	3.5	2.5	2.5	2.5	2.5	2.0	1.5	2.5	2.5	2.5
Median	2.8	2.7	2.0	2.9	2.8	2.6	2.6	2.5	1.9	2.5
A. Mean	5.42	5.45	4.51	5.50	5.03	5.05	4.66	4.86	3.95	4.94

* Since it is not possible to secure the time interval between the death of the first wife and the remarriage in terms of months it is evident that the use of years is not an exact calculation. If the wife died in 1923, for example, and the widower remarried in 1925, the interval is recorded as two years. In reality it may have been nearer three than two or nearer one than two years. These variations probably offset each other when there is a sufficiently large number of cases. In calculating the crude mode the middle of the class interval in which the largest number of cases fell was used, and for the median the value was determined by interpolation into fractions of years. There seems to be no significant correlation between the age of the husband at the time of the death of the spouse and the amount of time which elapses before a second marriage.

† Only the first five-year intervals are given here.

tions. The crude mode indicates that a good proportion of them remarry within two years after the death of the first marital partner.

The statistical averages for the engineers are probably typical, though, as mentioned above, the sample (67) is too small for the purpose of drawing valid conclusions. The crude mode for this group is one and one half years. Their early remarriage is probably explained by the fact that traveling around from one location to another, away from friends and relatives, the natural inclination is to seek another wife shortly after the death of the first.

The business men, lawyers, educators, public officials and physicians and surgeons seem to be in about the same class, though the business men and the lawyers seem to take a little longer than the others. If this is generally true, there is no apparent reason for it.

Whether the men who are listed in "Who's Who in America" are, in their remarrying habits, typical of those engaged in their respective occupations and professions, may perhaps be open to question. But at least they would seem to be representative of the upper strata in the various vocations that are listed in this study.

THE RAW MATERIALS OF EVOLUTION

By THEODOSIUS DOBZHANSKY

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FOR nearly eighty years evolution has been one of the basic problems of biology. During this time, however, the problem itself has undergone a most significant change. Darwin and his immediate successors had to prove first and foremost that evolution has actually taken place in the history of the earth. In this they were signally successful: for several decades no informed person has doubted, although some uninformed ones occasionally did, that the organisms now living have descended from very different organisms that lived in the past. Granted that evolution remains a very probable theory, not a fact; there is no more reason to doubt the validity of this theory than there is, for example, the existence, rise and fall of the Roman Empire.

Our intellectual curiosity is not satisfied, however, with knowing merely that evolution has happened in history. It remains to be found out what are the mechanisms responsible for the evolutionary transformations of living matter. An analogy with human history may be illuminating here. Once the fact that civilizations have risen and fallen in the past is established, an historian proceeds to examine the chain of events that has taken place in every particular instance, with the aim of discovering the underlying causes of the phenomenon itself. Now, it is patent that although the history of some civilizations is known in some detail, nothing but guesses have been advanced to explain their fate. With respect to organic evolution the situation is uncomfortably similar. Evolution has been, no doubt, going on, and at least for some groups paleontologists are able to sketch its actual course. But the mechanics of evolutionary changes has proved so elusive that geneticists, on whom the study of this subject has devolved, merely begin to see dimly their way to the goal. The mechanics, the physiological rather than the historical aspects of evolution, is what occupies our attention now.

FUNDAMENTAL UNITS OF HEREDITY AND EVOLUTION

An exact study of any natural phenomenon is greatly aided by the introduction of generally agreed upon units of measurement. It is no secret that the progress of evolutionary studies has been hampered by the failure to define such units in this field. Since evolution is essentially a change in the hereditary endowment of the succeeding generations, the units of heredity are the only ones that are likely to prove useful as units of evolution. Now, by far the greatest achievement of genetics to date is the establishment of the fact that the hereditary materials transmitted from parents to offspring are composed of discrete particles known as genes. Another fact of importance is that genes have their physical abode in the microscopical cellular elements known as chromosomes. Each chromosome contains not only a definite set of genes, but the latter are arranged within the chromosome in a fixed linear order. The kind of genes an organism carries and the manner in which they are distributed in the chromosomes determine, together with the environment in which the organism develops, all the external and internal characteristics.

In general, genes are remarkably stable and are passed from generation to generation without change. The same stability must be ascribed to the chromosome

structure: the gene arrangement is transmitted from parents to offspring, close and remote. The permanence of the gene and chromosome structure insures heredity, and is, of course, the antithesis of evolution, which implies a change of these constants. Yet, from time to time genes undergo sudden alteration, technically known as mutations. A mutated gene also faithfully reproduces its like and is transmitted to the offspring of the mutant individual as long as another mutation in the same gene does not take place. Similarly, the gene arrangement in a chromosome may undergo sudden changes, analogous to gene mutations. An altered chromosome is passed to its offspring until a new alteration interrupts this process.

Gene mutations and chromosomal changes are the elementary evolutionary steps which have been observed in many animals and plants in carefully controlled laboratory experiments. As a working hypothesis, subject to proof or disproof by further studies, we may assume that genic and chromosomal changes are the fundamental units also of the evolutionary process enacted in nature. Is it possible that such changes have brought about the entire variety of living organism which exists on the earth?

"Natural" Mutations

In well-studied organisms, particularly in the vinegar fly Drosophila, hundreds and even thousands of mutations have been observed to occur in laboratories. The general (or, perhaps, a better word here would be "superficial") characteristics of the mutation process are now rather well known. Mutations affect all sorts of characters. In the Drosophila flies mutations differ from normal or wild representatives of their species in the coloration of the eyes or the body, size and shape of the wings, bristles, eyes, legs, in the structure of various internal organs, in physiological characteristics such as reactions of the fly to light and gravity. Important organs may be drastically modified or altogether absent in mutants; thus, mutants are known having no eyes, having reduplicated legs, two instead of one pair of wings, changed sexual parts, mouth organs, antennae, and the like. Mutations termed lethals destroy the fly at various stages of its development, from early embryo up to the adult stage, or produce pathological changes resembling tumors in one or the other part of the body. If no artificial means to reduce them, such as x-rays, are used, mutations are on the whole rare. Mutation rates in most individual genes are probably less than of the order 1:10,000 per generation. Most mutations are recessive to the normal or original condition, that is to say a fly carrying the mutated gene in one chromosome and its normal counterpart in the other chromosome is normal in appearance (every fly carries, of course, two chromosomes of each kind). Finally, mutations usually show various degrees of the reduction of the viability compared to the normal or wild fly and could hardly compete with the latter outdoors.

It is especially the last of the above properties of mutations that has caused a number of eminent biologists to doubt not only that mutations could possibly play a constructive rôle in evolution, but that they occur at all in the natural state. Indeed, if instead of investigating the Drosophila flies coming from laboratory culture bottles we examine a sample of flies caught wild, an impression of surprising uniformity is likely to be gained. To be sure, some mutations can occasionally be discovered among wild flies, but their frequency is, by and large, negligible.

A lasting credit is due to the Russian geneticist, Tschetwerikof (Chetverikov), who has demonstrated that the ostensible uniformity of wild populations of Drosophila is merely a deceiving appearance. Since most of the mutations are recessive, a fly carrying one mutated and one normal gene is not distinguishable from normal. It follows that an inspection of wild flies is quite insufficient to detect mutations that may be present in them.

In order to bring mutations to the surface, a special genetic technique must be devised to obtain flies carrying a given chromosome twice instead of once. Chetverikov and his co-workers have tested the offspring of 239 wild *Drosophila melanogaster* flies collected in a certain locality in Caucasus, and found that more than a half of them carried one or more mutations in their hereditary materials.

Mutations in Wild Populations of Drosophila pseudoobscura

The results of Chetverikov's work have been confirmed and extended by several investigators, among whom Dubinin in Russia and Sturtevant in America must be mentioned most prominently. In collaboration with Miss M. Queal, the present writer has secured similar data for wild populations of *Drosophila pseudoobscura* inhabiting certain mountain ranges in California and Nevada. Samples of the fly population were taken in eleven separate localities, the flies brought to the laboratory, and certain crosses arranged as a result of which individuals carrying the same wild chromosome twice are produced. The characteristics of such individuals are then compared with those of normal wild flies. Only one chromosome has been studied in these experiments, although the fly species in question possesses five pairs of chromosomes.

The flies collected outdoors were in every respect "normal" or "typical" representatives of their species. They were quite uniform in appearance, although some of them were, of course, larger or more robust than others. This variability is not inherited, being due to the influence of the external conditions in which the fly larvae develop (mainly an abundance or a scarcity of the food supply). Yet, despite the external uniformity, between 3 and 4 per cent. of the wild chromosomes proved to carry mutations provoking more or less striking visible changes in the structure of the flies. Some mutants change the normal red eye color to an orange or a purplish one, others cause spoon-shaped or notched wings, polished body surface, etc. Some of these mutations are probably identical with types having appeared previously in laboratories; others are new ones. However, unexpectedly large the frequency of these mutations may seem to us, it is far exceeded by the frequency of mutations that produce no noticeable change in the structures of the fly's body, but that cause instead a change in the viability of the insect.

No less than 11 per cent. of the wild chromosomes proved to carry recessive lethal mutations. As stated above, a lethal is a gene that causes death of the individual in which it is present in double dose. Lethals are known to be one of the most frequent types among the laboratory mutations, but one is somehow unprepared to see the wild populations too replete with these death-dealing hereditary changes. Between 3 and 4 per cent. of the wild chromosomes are infected with semi-lethals, which reduce the viability of their carriers more or less drastically, but still permit some of the flies to survive. Finally, very many of the wild chromosomes contain genes that produce slight, although perceptible, deteriorations of the viability. Exactly how large is the proportion of such chromosomes is not an easy matter to determine, but it is likely to exceed 50 per cent. A minority, possibly not more than 10 per cent., of chromosomes seem to be free from genes reducing the viability, and a very small minority appears to carry genes that are favorable, at least under the conditions in which the experiments have been carried out.

Aside from the genes producing visible external effects and those manifesting themselves in a modification of the viability of their carrier, wild populations possess a wealth of mutants of still other kinds. Among these, genes influencing the development rate of the fly seem to be very common. Although minor variations occur, the genetic conditions encountered in all eleven populations

studied proved to be essentially similar; all populations are infected with mutants to about the same extent. The situation found in our samples of the natural populations of the fly appears to be not an accident or an exceptional occurrence, but a typical state of affairs in a species propagating itself by cross-fertilization. It is justifiable to conclude that mutations are so frequent in nature that not only every individual but probably every chromosome carries one or more mutant genes. The reason why this fact has been overlooked for so long is, however, simple enough: mutations are concealed in the hereditary materials of the organism due to a majority of them being recessive.

Chromosomal Changes in Natural Populations

The time is not so remote when chromosomal alterations, especially the variations in the gene arrangement in the chromosomes, were considered rare phenomena. About ten years ago Muller did a great service to biology by showing that chromosomal alterations can be induced artificially by x-rays treatment. Now we are in possession of data that show that these once genetic oddities are not at all rare in wild populations. An example dealing with the already mentioned fly, *Drosophila pseudoobscura,* will suffice. Strains of this fly were secured from various parts of its geographic range, extending from British Columbia to Mexico and from the Pacific to Texas. One of its chromosomes, namely the Y-chromosome, proved to be variable in size and in shape; seven different types have been distinguished, each type being restricted to a definite part of the specific distribution area. Sturtevant and the writer have detected seventeen structural types in the third chromosome of the same fly, five in the second, two in the fourth, and four in the X-chromosome. Again, each type of chromosome structure is present only in flies inhabiting a certain region, although in many localities several types are mixed in the same population.

The Viability Paradox

It is clear from the foregoing discussion that an enormous supply of genetic variability, both in the gene and in the chromosome structure, is present in natural populations. This variability is comparable to that which is known to arise in carefully controlled experiments in genetic laboratories, and it is also similar in kind to the structural elements into which the differences between natural races and species can be resolved. Yet, a theory that would endeavor to assign equality to these three phenomena is confronted with an obstacle that may seem well-nigh insuperable. Indeed, most mutations obtained in the laboratory and found in wild populations are deleterious to the organism. In fact, many of them are lethal. It would seem, then, that the presence of such mutations in nature presages an eventual catastrophe to the organism rather than a progressive evolution. It is no idle phrase to say that the situation is an extremely challenging one. In the following paragraphs an attempt is made, however, to indicate one of the possible escapes from the apparent impasse.

The viability effects produced by a mutation or a chromosomal change are not a fixed or unchangeable quantity. On occasion the viability effects of a gene may be changed in the presence of other genes. Two mutations taken separately may produce decreases of the viability, but a combination of the same mutations may display any viability, from a very low one to normal. Moreover, a mutation which in a certain environment is deleterious may prove to be favorable in other environments. No better example of this situation can be demanded than that furnished by Banta and Wood: a mutation in a species of water fleas does not survive at a temperature that is optimal for the ancestral type, but the same mutant is viable at a higher temperature which is

unsuitable for the latter. Unless the properties of the genetic and the secular environments in which the viability effects of a given mutant are studied are known in detail, the results of the studies are ambiguous. All that we really know about mutations encountered in wild populations of Drosophila is that in the environment in which the flies have been kept in our experiments a large majority of the mutations are deleterious. There is no basis for the assertion that these mutations will be deleterious in every possible environment. This does not mean, of course, that an environment may be found in which every mutation will be favorable; one simply must refrain from making conclusions too fast.

Adaptation

It is axiomatic that the life of an individual or a species can endure only so long as a certain equilibrium between the organism and its environment is maintained. It is not axiomatic, but nevertheless true, that for most organisms the equilibrium is precariously unstable. One may be tempted to speculate that in an eternally constant environment all the survivors may become so ideally adjusted that the best of all possible worlds could at last emerge. This inference may justly be doubted, and in any case the question has no more than an academic interest, for in reality the environment is not constant, neither on the geological nor on the everyday scale. The organism must, therefore, either change itself in conformity with the demands of the new environments, or face extinction.

On the individual level the adaption is accomplished, within limits, with the aid of various physiological regulatory mechanisms. On the species level adaption involves a change in the genetic makeup, a succession of mutations, evolution. The crucial question is whether or not the living organisms can react purposefully to the demands of the environment, by producing those, and only those, mutations that are desirable in a given set of conditions. The whole sum of our knowledge argues in favor of a negative answer to the above question. To all appearances, mutations are random changes of the gene structure. Natural selection can pick out those mutations that are useful at a given time, but it can not prevent the concomitant origin of neutral and harmful ones.

A genetically uniform species may be in an advantageous position in a static environment, provided it has become adapted to it. But such a species will be threatened as soon as the environment changes, for it will be then devoid of the materials from which adaptations can be built. Conversely, a species possessing some genes that are deleterious in the present environment but advantageous in others may be better off in the long run. Here it must be kept in mind that these deleterious genes manifest themselves only seldom, when individuals having them in double dose are produced. Even if a majority of mutations are not useful in any circumstances, it may be desirable for a species to withstand their presence for the sake of a minority that may save its existence eventually.

Adaptation is not given to the organism as a gift. It must be purchased at a price, and the price is from our human standpoint, a revoitingly high one. However seldom the deleterious genes present in the species populations may manifest themselves, still some individuals in every generation succumb to their action. Paradoxically enough, it is the loss of these individuals that guards the species as a whole from extinction. The general picture of the mechanism of evolution thus arrived at will certainly be far from pleasing to those who regard nature as an embodiment of kindness. The writer must confess that this picture is not pleasing to him either. The words "good" and "bad" are not to be found, however, in the scientific lexicon. In this lie simultaneously the greatest strength and the greatest weakness of science.

HAHNEMANN AS A CHEMIST

By Dr. ISRAEL S. KLEINER
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"I do not know whether I am mistaken, but it seems that one can obtain more truths, important to Humanity, from Chemistry than from any other Science."

Thus wrote Samuel Hahnemann, destined to be a leading figure in one of these other sciences—medicine. They were the opening words in an article[1] describing his test for lead and iron in wine, and testified to his opinion of "this divine art" (diese göttliche Kunst). Although at that time (1788) Hahnemann was a practising physician, he probably was more active as a chemist. The greater part of his small income during his early manhood was derived from his chemical activities. This phase of his life is mentioned by all his biographers, but how excellent a chemist he really was has generally not been appreciated.

It has usually been assumed that Hahnemann received no schooling in chemistry, *i.e.*, that he was self-taught as regards this science. "In fact," says Hobhouse,[2] "the course of medical training prescribed at the university did not at that time include these subjects (chemistry and microscopy): even so famous a university as the one at Heidelberg did not introduce microscopy and chemistry in the syllabus of their medical students until 1845." It is difficult to see how any one with no training could master even the simple chemistry of that day so well that he could accomplish the important work which Hahnemann soon did.

However, such an assumption is no longer necessary. Tischner[3] has shown that Johann Gottfried Leonhardi lectured in chemistry at the University of Leipzig while Hahnemann was a student there and in the winter of 1776 gave an *experimental* course in chemistry. Since Hahnemann twice refers to Leonhardi as his teacher, it must be inferred that he studied chemistry under that instructor. He took medical courses at Leipzig from 1775 to 1777 and in the hospital at Leopoldstadt, near Vienna, in 1777. During this time he must have acquired his basic knowledge of chemistry. He obtained the degree of doctor of medicine at Erlangen in 1779, but his chemical activities continued, during his struggles to become established as a physician, until about 1789.

In evaluating his contributions, one must take into consideration the state of chemical knowledge and philosophy of his time. The last quarter of the eighteenth century covers the period of the Chemical Revolution, which eventually completely upset the current views of chemistry. It is doubtful whether Hahnemann realized the extent of this change in chemical thought, although he must have been familiar with the writings of Lavoisier, Priestley and others, as he was an accomplished linguist and an indefatigable reader. Very few chemists were able to understand how great a change in chemical theory was taking place, how beautifully the new hypotheses would explain known phenomena and how rapidly chemistry would develop as a result of Lavoisier's work. Even Priestley and Cavendish, who contributed so much to the new chemistry, interpreted their findings in terms of the old, refusing to abandon the phlogiston theory.

Although the phlogiston theory had its origins much earlier, it was developed and enunciated most clearly by Stahl, toward the end of the seventeenth cen-

1 Samuel Hahnemann, *Chemische Annalen (Crell's)*, I: 291–305, 1788.

2 Rosa Waugh Hobhouse, "Life of Christian Samuel Hahnemann, Founder of Homoeopathy," London, 1933.

3 Rudolph Tischner, "History of Homeopathy," translated by Linn J. Boyd, *Jour. Am. Inst. Homeopathy*, 27: 548, 622, 672, 728, 1934. 28: 34, 225, 288, 358, 555, 602, 684, 749, 1935.

tury. According to this theory all combustible substances contain one constituent which escapes during combustion. It is easy to see how the early chemists came to have this conception. When a piece of wood burns, the flames appear to come out of it and the residue is distorted by this violent emergence. Naturally they concluded that something had left the wood. The alchemists first called this "sulfur"—Becher termed it "terra pinguis," while Stahl named it "phlogiston." Some substances burn more completely than others; this was explained by saying that they have more phlogiston in their make-up. Phosphorus burns to a white ash, which, when dissolved in water, is acidic. Therefore, they argued, phosphorus is a compound of phlogiston and phosphoric acid. If a metal is heated, an ash (which we call an oxide) is left—hence the metal consists of this ash and phlogiston. Now, when this calx (oxide) is heated with carbon, the carbon, (thought to be rich in phlogiston) transfers its phlogiston to the metallic ash and the metal (ash plus phlogiston) is reconstituted. Of course, we now see that the metallic oxide has been reduced to the metallic form by heating with carbon, the carbon being oxidized in the process.

There were several difficulties involved in accepting this hypothesis. The first was that no one had ever isolated phlogiston, even in an impure form. Another—and more serious one—was that when metals are burned, the ash weighs *more* than the original metal. If it loses phlogiston, it should weigh less. These flaws—and others—were shown very plainly by Lavoisier (1743–1794). This scientist in a series of remarkable experiments on combustion demonstrated the fallacy of the phlogiston hypothesis very brilliantly and in 1777 enunciated his own theory of combustion, which he later broadened to include combustion in the animal body. Lavoisier's views are essentially those held to-day. It took a number of years, however, before they were accepted even by his contemporaries in France. Since Hahnemann was a master of French it is probable that he was among the first in Germany to study Lavoisier's work. Haehl[4] says, "Hahnemann became acquainted, in Dresden, with the famous French chemist, Lavoisier, who was at the time passing through Dresden." If this occurred—and Haehl gives no authority for his statement—it must have been between 1785 and 1789, and in 1788 he used the expressions "phlogistierter" and "dephlogistierter."[5]

It is probable that Hahnemann's early chemical studies were entirely from books—although he possibly saw laboratory demonstrations by Leonhardi. His first real contact with a laboratory was made in 1781 when he moved to Dessau. This was not far from a mining district in the Harz Mountains and when he began to study metallurgy he naturally required some laboratory facilities for this work. These were found in the local pharmacy of Herr Haseler, whose step-daughter proved an added inducement to visit the shop. He fell in love with her and later married her. It must have been this intimate relationship with the pharmacist and the use of his equipment which enabled Hahnemann to get a first-hand knowledge of drugs, their manufacture, adulteration and the various problems of the pharmacist. The pharmacists in those days were almost the only chemists. Of course, there were a few teachers of chemistry in the universities and a few independent savants, and, perhaps, still some alchemists. There was also some

[4] Richard Haehl, "Samuel Hahnemann, His Life and Work," translated by M. L. Wheeler and W. H. R. Grundy, London, 1922; Hobhouse (footnote 2) makes a similar statement and cites Ernst von Brunnow ("A Glance at Hahnemann and Homoeopathy," Leipzig, 1844, translated by J. Norton, 1845) as authority for the assertion that Hahnemann corresponded with Lavoisier.

[5] Samuel Hahnemann, *Chemische Annalen* (*Crell's*), I: 141–2, 1788.

chemical manufacturing. But the names pharmacist and chemist were almost synonymous and even to-day this is the case in many parts of Europe. Hahnemann remained at Dessau only a short time and then moved to Gommern. This town was not very far away, so that he still could use Haseler's facilities, as well as those of the pharmacist in his new location. The new situation, although yielding a better salary than the former, gave him little clinical work, and consequently he had more time for chemical study and investigation.

These studies directed his attention to a book by Demachy on the wholesale manufacture of chemicals. This was a work of great importance because it described methods which had been kept secret by manufacturers, particularly the Dutch. Hence Demachy's book had been welcomed by the French and by those of other countries who read that language. Hahnemann now translated it into German, and, because of his familiarity with pharmaceutical chemistry and his indefatigable reading of the literature, he was enabled to enlarge and improve it. After he had finished translating this work, but before publication, another translation, by Struve of Berne, appeared. This also had some new material. Consequently, Hahnemann included Struve's comments and published the enlarged work. He supplied missing references to the literature—in fact, he frequently cited a number of additional authorities whom Demachy and Struve had overlooked—and amplified with details, as, for example, the history of a discovery, the chemical reactions involved and various manufacturing details which had escaped Demachy.

It is not surprising that many erroneous ideas were presented. For example, the purity of nitric acid was estimated by the amount of white precipitate produced when a silver solution was added to it. This, of course, was caused by hydrochloric acid present. "Such impure nitric acid must indeed have acted as aqua regia, and it is therefore not astonishing that that excellent chemist, Struve, observed a deposit of gold from a 'solution of silver.' (Hahnemann calls this idea 'an alchemistic fancy.')"[6] This parenthesized remark is interesting as intimating where Hahnemann stood on the subject of alchemy, in a day when alchemy was not completely discredited. Other interesting misconceptions were that the older potash becomes the more potassium sulfate it contains, that milk sugar consists of one part chalk and three of saccharic acid, and that cinnabar (mercuric sulfide) owes its red color to the fatty acid which it has derived from fire. Since this was published in 1784, it is not strange that his discussions should include references to phlogiston. It was not until several years later that Lavoisier's conclusions were generally accepted.

In spite of these errors, the work was extremely valuable, and many of the errors of the original were corrected by the translator. Several new tests were added by Hahnemann. The test for hydrochloric acid at that time was "lunar caustic" (silver nitrate) alone. This might precipitate sulfuric as well as hydrochloric acid unless a considerable degree of dilution was used. Hahnemann used a solution of silver sulfate, which of course would not precipitate sulfuric acid. He also proposed a new test for sulfuric acid (lead chloride) and described Scheele's new baryta reaction for the same acid. This book was very well received and, indeed, was standard for several years. A new edition was issued in 1801.

A number of papers by Hahnemann appeared from time to time in the journal, *Chemische Annalen für die Freunde der Naturlehre, Arzneygelahrkeit, Haus-*

[6] Wilhelm Ameke, "History of Homeopathy," translated by A. E. Drysdale, London, 1885.

haltungskunst und Manufacturen, which was edited by Lorenz Crell. Some of these were "preliminaries" to parts of his books or omissions from them or amplifications of procedures previously described. They abound in detailed descriptions of technique, resembling very closely the directions for preparing homeopathic medicines which he later published. For example, in his work, "On the influence of different gases on fermentation of wines,"[5] he explained how he introduced the wine (eight-year old Meissner) and the gases into flasks, the amounts of each used, the method of hermetically sealing them, and the temperatures at which they were kept for two months. They were shaken "thrice daily with thirty strokes up and down," and he assures us that all were agitated to about the same degree. His experiments always were carefully performed and meticulously described.

A monograph on arsenical poisoning was published by Hahnemann in 1786. In it he gave the determination of the lethal dose, pathological effects as well as the best methods of analyzing for arsenic. He suggested several tests for arsenic, some of which are still recognized, *e.g.*, the use of an ammonium cupric salt (Hahnemann used the chloride) to precipitate the bright green cupric arsenite (a reaction which he found to be positive at a dilution of 1 in 5,000.) He also recognized the necessity of an acidic reaction in the precipitation of arsenical compounds by means of hydrogen sulfide and thus demonstrated the reason why others had found this reaction indefinite. This apparently minor point of acidification in certain qualitative tests is exceedingly important.

A little later he translated, and, as was his habit, improved and enlarged J. B. Van den Sande's "La falsification des medicaments devoilee." This handbook on the adulteration of drugs contained much useful information, including methods of testing for adulterants, solubilities of various metallic salts and the relations of the specific gravities of acids to their concentrations. It was in this volume that his celebrated "wine test" was described. This was really a test for lead as distinguished from other heavy metals. It is stated that simultaneously and independently Fourcroy made and published the same test in France. Lead was often added to wine in those days, probably for the preservative effect, and lead poisoning resulted frequently from its use. It was necessary, therefore, to test wine for lead in court cases resulting from poisoning and in suspected wines. The current test was to add "arsenical hepar sulphuris" to the wine. This reagent was prepared by boiling two parts of arsenious sulfide with four parts of unslaked lime in twelve parts of water. This reagent when added to wine containing lead salts would produce a dark precipitate of *lead sulfide*. However, other metals would yield a similar result. For example, any iron present—as might result from the presence of pieces of iron chain or iron screw heads in the cask—would give a positive reaction. It sometimes happened that innocent dealers were convicted on the strength of this test. Hahnemann, realizing the inadequacy of the test, determined to attempt to evolve a better one. After careful study, he came to the conclusion that a satisfactory method was to add hydrogen sulfide water ("Leberluftwasser") and then acidify.

Lead sulfide, a black precipitate, forms under these conditions, but iron sulfide is soluble in the acid. Again the importance of optimum hydrogen ion concentration! It is not a specific test for lead, but the metals which give positive reactions either would not or should not be in wine, *e.g.*, silver, copper, mercury, arsenic, etc.

Hahnemann's directions for preparing the reagent were as follows. First

"hepar sulphuris calcareum" is prepared by heating at white heat for twelve minutes equal parts of oyster shells and sulfur. The whitish gray powder, the essential ingredient of which is calcium sulfide, may be kept unaltered for years. Two drachms of this are placed in a bottle, a pound of water added and ten drops of muriatic acid for every ounce. The strength of acid is not stated, but presumably the strongest then available was used. If this reagent is added to wine, a black precipitate indicates a considerable amount of lead, a brown to brownish-yellow discoloration points to small quantities. In the presence of acid iron does not react. Although the first description called for muriatic acid, later cream of tartar was used and still later Hahnemann called attention to the fact that his technique must be followed exactly or else failure might result. In order to be sure of the acid reaction he then described his new "Liquor probatorius fortior,"[7] which consisted of tartaric acid and calcium sulfide ("Kalkschwefelleber"). To-day the acid is added directly to the suspected fluid and hydrogen sulfide gas is bubbled in—but the same principle is involved. In Hahnemann's hands, the test was positive up to a dilution of 1:30,000.

A *quantitative* method for lead was soon worked out in which the metal was precipitated as the sulfate. After filtering and drying, this was weighed and due allowance was made for the solubility of this salt.

It is thus seen that Hahnemann was an excellent chemical investigator, not a mere analyst following slavishly the methods he found in vogue. He was ingenious in improving apparatus and devising new appliances. He was careful and exact in his quantitative measurements. He had an almost uncanny power of sensing how a reaction would proceed. When one realizes the flimsy foundation upon which chemistry rested in those days, Hahnemann's accomplishments—of which but a part have been mentioned—must be termed remarkable. It has been asserted that Hahnemann was really the founder of colloid chemistry. This is based on the pronouncement that "all medicinal substances brought into potency 1 (one-millionth) by trituration in powder are soluble in water and alcohol."[8] The procedure, he asserted, was unknown to chemistry and was "a discovery which I announce to the world for the first time." It is evident that he was probably the first to produce suspensoids by his process of repeated trituration and dilution, but since he did not study their nature and properties physico-chemically, we can hardly dislodge Graham in favor of Hahnemann.[9] In fact we must remember that these preparations were made for medicinal purposes, long after Hahnemann's chemical career had ended.

It is idle to speculate upon his probable place in chemistry if he had continued in this science. With such contemporaries as Lavoisier, Priestley and Cavendish he would have had competition which might have stimulated him to extraordinary activity or might have overshadowed him completely. In medicine his place is unique and his importance is being recognized more and more. That he was not only a medical pathfinder but a good chemist—perhaps a potentially great one—adds another name to the list of versatile scientists, such as Abbé Spallanzani, Lavoisier, Benjamin Franklin and Pasteur.

[7] Samuel Hahnemann, *Chemische Annalen* (*Crell's*), I: 104–111, 1794.

[8] Samuel Hahnemann, "Chronischen Krankheiten," 1828, Vol. II, p. 5; quoted by Tischner (footnote 3), p. 674.

[9] Linn J. Boyd, "A Study of the Simile in Medicine," Philadelphia, 1936. See p. 38.

COMMENTS ON CURRENT SCIENCE

By SCIENCE SERVICE[1]

WASHINGTON, D. C.

THE FINANCIAL SUPPORT OF RESEARCH

Research is the lubricant that makes the wheels of civilization turn faster. Without it, industry and agriculture would not accelerate but would slow down and perhaps even stop all together. The financial support of research is therefore important. It is a matter of more than idle curiosity as to how many dollars are being spent for research, dollars plowed back into our workaday world to produce more scientific dividends in dollars and better living.

In good round figures, somewhat over a cent is spent for research out of each dollar grossed by U. S. manufacturing and agriculture, according to figures collected from a score of sources. Industry spends more than agriculture, 1.7 per cent. (some $250,000,000) out of the $14,690,000,000 gross manufacturing income of 1936. Agricultural research, almost wholly by state and federal institutions, used 0.37 per cent. or some $35,600,000 of the estimated $9,530,000,000 cash farm income and value of home consumed farm products combined.

In terms of population, the total for research expenditures in these two great fields is only a couple of dollars per person in the U. S.

When such compilations are made, the question arises as to what to include in the figures for research. The historian who is looking into some problem can rightly say he is engaged in research. But the figures quoted are largely for inquiries and developments in the physical and natural sciences, the fields in which chemists, physicists, engineers, biologists, etc., work.

Chemical concerns practice research to a larger extent than the average. Here are some reports: 2.3 per cent. of net sales; 2.4 per cent. of gross sales; 5 per cent. of net sales; 7 per cent. of net sales, etc.

Medicine and health fields see considerable expenditures for research, the results of which are mostly measured in better health and less human suffering.

Research pays magnificently, often thousands of per cent. in dollars and more in gains to civilization.

THE STROBOSCOPIC CAMERA

Ranking with the microscope and the telescope as a scientific aid to human eyes is the high speed stroboscopic camera that has reached a peak of development at the Massachusetts Institute of Technology.

Our eyes can not see things that are moving with great rapidity. If we "freeze" a hundred thousandth of a second of some speedy motion by illuminating it with a spark of such extremely short duration, the scene will appear motionless. It can be recorded upon a photograph so that we can look at it for a longer time than that very short interval.

That is what is done by Professor Harold E. Edgerton and his associates, K. J. Germeshausen and H. E. Grier in laboratories on the Cambridge, Mass., campus. They can catch a bullet coming out of a rifle's muzzle, the dangerous shiver of high speed machines, and other happenings that better the proverbial wink of an eye.

Far from being just a stunt, such

[1] Watson Davis, director, Frank Thone, Robert D. Potter, Jane Stafford, Emily C. Davis and Marjorie Van de Water, staff writers.

speedy stroboscopic photography promises to be extremely useful practically. Professor Edgerton has a unique ultra motion picture camera that can speed up to 6,000 exposures per second. Linked to the brilliant spark-flashing stroboscope, this camera runs at such closely controlled speeds that precise measurements of accelerations, velocity and other factors can be made on the film.

The "studio" for photographically "seeing the unseen," contains a whole roomful of electrical apparatus, mostly concerned with producing suddenly released high voltages that produce the photographic sparks.

The stroboscopic camera is eminently suitable for clocking projectiles, whirling engines and propellors and other mechanical devices, but even medicine is using it to study the action of high speed microorganisms.

WARM WALLS AS A METHOD OF HOUSE HEATING

It was Mark Twain who said that every one talks about the weather but no one does anything about it. Each year, however, science and engineering make the famous humorist's quip slightly less applicable.

Weather, of course, is only another name for man's atmospheric environment. At least that aspect of weather is one of the most important to human welfare.

As Professor Earle B. Phelps, of the College of Physicians and Surgeons, Columbia University, recently said, "By means of clothing, umbrellas, shut-in cars and other sheltering devices we do maintain, even in our travels, a sort of personal weather environment and, when we confine the weather within walls, we do with it as we will."

Health and comfort, Professor Phelps goes on to add, demands a balance among the various manners of heat loss of the body in addition to an over-all balance between production and total loss. "An arctic explorer, in his furs, and a swimmer in the surf of Atlantic City may both be disposing of the same number of calories per hour, but one would hardly class the two environments as equivalent," he declared. Yet each man might, at the moment, be equally comfortable.

Indoors it has long been recognized that air temperature, humidity and movement are all factors in determining comfort. But also it is now recognized that there is a fourth factor, the temperature of the walls of the room. It has been shown that radiation from the body to the walls may account for nearly half the body's total loss of heat. It has been on these findings that home heating of the future has often been predicted as consisting of heated walls.

STATIC ELECTRICITY IN THE SEPARATION OF ORES

Every small boy who has ever rubbed a piece of sealing wax with cat's fur and attracted to it bits of paper knows that in the forces of static electricity lies one means of separating materials. Mining engineers long ago realized that somehow static electricity might be used commercially to separate valuable from worthless ores.

The idea is old, of course, but it never has been applied widely and successfully to large-scale separation of ores as have the magnetic separation and various flotation methods. The trouble was that the sources of static electricity—the old-fashioned Wimshurst machines and so on—were ineffective. Later the use of transformers and mechanical rectifiers of current arrived and some improvement came also. But, as H. B. Johnson reports to the American Institute of Mining and Metallurgical Engineers, there has been little development in the last ten years despite great advances in the radio and vacuum tube art in that decade.

Mr. Johnson has studied the electrostatic separation of over 90 different elements with a simple and ingenious apparatus. The mineral mixture to be separated feeds down a hopper on to the surface of a rotating cylinder charged electrically positive. Nearby this cylinder is another one charged with electricity of the opposite sign by using a full-wave high-voltage rectifying tube. The voltage created sets up a strong electric field that pulls the falling particles out of line in their vertical fall and makes them drop on the other side of a suitable vertical dividing sheet of material. Thus one component of the mixture falls on the one side and the unattracted particles on the other.

Mineral granules the size obtained in commercial grinding machines were used in the tests. One difficult separation achieved was the removal of bituminous coal dust from anthracite dust. Among the difficult separations made possible were those of separating (1) galena from pyrite, (2) muscovite from lepidolite (both micas) and (3) calcite from dolomite.

A TUNG OIL SUBSTITUTE

Japan is conquering China foot by foot. Already the economic consequences of their control are felt in the world markets, mainly as a stopping of Chinese exports like tung oil. Realistic business sees conditions becoming worse before they become better and hence is enlisting the aid of scientific research to find some substitute for the fast-drying vegetable oil which finds such wide use in paints and lacquers.

Which brings us to oiticica oil. This oil comes from pecan-like nuts from Brazil's oiticica tree. Oiticica oil (pronounced oy-tee-see-kar) is the only vegetable oil, available in commercial quantities, which rivals tung oil in its properties.

While you can follow the Japan-China troubles in the newspaper headlines you can also read them, by inference, from the tables showing Brazil's exports of oiticica oil. Prior to 1934 these exports were negligible. In 1935 exports of oiticica oil totaled 4,000,000 pounds and in 1936 they jumped to between 8,000,000 and 10,000,000 pounds. In 1936 the United States took 3,000,000 pounds of the total and in 1937 the amount increased to 4,000,000 pounds. World export figures for 1937 are not yet available.

Research is showing how the oil can give both smooth and crinkly surfaces to paints and lacquers. Early work, in which the oil was processed like tung oil, gave discouraging results that are now being overcome.

Oiticica oil seems especially adapted for use with phenolic resin lacquers of which bakelite is typical. The crushing of the nuts in northern Brazil is now done in modern factories which bid fair to set up a new oil source despite any events which may occur in the Far East. Chemists in Germany, England and France, as well as the United States are studying the oiticica oil.

FLYWAYS OF BIRDS

Birds flying northward, as heralds before the face of the returning springtime sun, follow paths as definite as those laid out for pilots of transcontinental planes. These can be traced by noting numbers on leg-bands of captured birds and then releasing them again, and also in a more general way by observers stationed at strategic points along the "flyways."

North America has four major flyways, with of course a number of feeders and branches. The four great paths follow Atlantic and Pacific coastlines, and in the interior, one along the east flank of the Rockies, over the Plains, and one down the great central valley with the Mississippi as a broad silver guideline.

Europe likewise has well-established

flyways. Two of them cross Switzerland. One, originating in Russia, skirts the Baltic countries, Poland and Germany, and thence into northwestern Switzerland. The second comes from Finland and northern Scandinavia. At the Rhine delta it divides. One branch toward the south goes *via* the coast of France and the Iberian peninsula. The other swings inland along the Rhine and eventually reaches northwestern Switzerland.

Unlike our North American birds, the birds of Europe that follow these inland routes have mountain barriers to climb. Passes become as important to them as to land animals—or even to airplanes. Thus is has come to pass that Switzerland is a strategic center for the study of migrating birds, and also that Swiss refuges possess high importance for the conservation of European bird life. In view of the ominous clouds now hanging over all Europe it is perhaps well for the birds that this is so.

WILD PIGS AND GOATS

Hawaii seems to have been a paradise that escaped the trampling hoofs and devouring mouths of the Age of Mammals, almost entirely until the coming of that most troublesome of all mammals—Man. To introductions and changes wrought by human agency are traceable most of the damage and destruction to the unique vegetation of the islands.

Some of these disturbances were described before the North American Wildlife Conference at its Baltimore meeting by Samuel H. Lamb, assistant park naturalist of Hawaii National Park. Although Mr. Lamb confined his discussion to problems within the national park boundaries, he stated that in many ways these are typical of conditions for the countryside at large.

The only mammal that seems to have found its own way to Hawaii unaided by man is the bat. The original brown-skinned immigrants brought dogs and perhaps pigs, and they may have carried rats and mice as stowaways. Other students of the problem believe that the pigs, rats and mice date from a supposed visit by the Spaniards in the sixteenth century. Goats were brought by Vancouver in 1794, and other live stock came later.

Of them all, most destructive to Hawaiian native vegetation are goats and pigs, escaped from domestication and now living as wild animals in the rough, wild interior, in part thickly forested, in part grassland and semi-desert lava fields. Goats are notorious everywhere as destructive feeders. Pigs are even worse, for they root underground, devouring bulbs and rootstocks, and breaking the ground cover to give alien grasses and weeds a chance to gain roothold.

Efforts to save at least part of the native vegetation include goat-tight fences around selected areas, followed by concerted drives to eliminate the feral animals within them. In broken lands where fencing can not be carried out, the only thing that appears practicable is to permit and even encourage wholesale shooting of the goats and pigs.

A CANADIAN BONE

Canada can prepare for scientific war. Discoveries of "oldest inhabitants" have begun to be reported. If experience of the United States means anything, from now on Canadians will be arguing endlessly over whether fragments of human bone and odd-shaped stone blades are evidence of Ice Age man in Canada, or just relics of later and less exciting Indian tribes.

The incident creating an early-man-in-Canada situation occurred when workmen digging gravel for a road near Bradwell, Saskatchewan, turned up something unexpected—a skeleton.

They called in Canadian mounted police; but the detective sergeant realized this was no murder mystery, at any rate, none of recent date. So, he called these

antique-looking bones to the attention of a scientist, who happened to be a chemistry professor at the University of Saskatchewan. The professor rounded up three more professors—a chemist, anatomist and geologist—and proceeded to the scene.

Meanwhile, the road builders hauled off more gravel. The scientists, thus confronted with a mystery scene much disturbed, have concluded tentatively that this unknown was a primitive man of considerable antiquity. In short, "an interesting example of early man in America."

As clues to antiquity, they mention the heavy, mineralized bones; also that the skeleton lay in gravel deposited when the Keewatin ice sheet was retreating, some 15,000 or 20,000 years ago. The bones are compared to those of Neolithic men of Europe. A nondescript stone tool was nearby.

And now, what next? Undoubtedly, some cautious scientist will rise to point out that this man could have lived after the Ice Age and be buried intrusively in glacial ground. Whether the skeleton is an ancient type, or just recent Indian, will be good for many an argument. Canada may yet find conclusive evidence of early inhabitants.

DIGGING SHOWS WHY ROME FAILED IN ANCIENT BRITAIN

Once again the past teaches a lesson in conquest and its results.

Archaeological investigation in England is revealing what written history has never explained: How and why Rome failed to Romanize barbarian Britain, 2,000 years ago.

Rome failed, says Dr. R. E. M. Wheeler, London University archaeologist, because Rome tried in Britain to introduce too revolutionary an upheaval in a social order.

Rome brought a pattern of city life which was new to the Britons because it centered around commerce. Excavations show that the Britons had their own cities. But the citified Briton was bucolic. He drew on the nearby countryside for food and for the stone, iron, clay, bone, and horn that made weapons and household gear. Rarely did these prehistoric Britons import foreign luxuries. Their trade was petty.

Came the Romans, and they set about improving these people. Native towns that resisted were stormed and dismantled, as has been recently shown by digging at Maiden Castle. Disarmed townsfolk remained to rebuild their houses and become Roman subjects.

The Romans introduced foreign craftsmen to teach the natives to build in the Roman way, and foreign capital to develop resources of the country.

By the middle of the second century, says Dr. Wheeler, London and Verulamium "shone brightly on the provincial landscape." Britain had acquired central heating, dust-proof floors, bath suites.

But, "little more than a century later the bubble had burst." Another century, and Romano-British cities degenerated into concentrated slums. No prosperous middle class had developed, and without this type the Roman city plan was bound to fail.

Dr. Wheeler sums it up: Rome effected a political and social revolution in Britain, but not the economic revolution to fit it. Romano-British country life succeeded. The cities awaited the middle ages for a come-back.

THE PROBLEM CHILD

Defiant, restless, truant and subject to temper outbursts. This is a picture of what school officials know as a "problem child."

It is also a typical picture of a child who has failed in learning to read, write and cipher—particularly to read, Dr. Charles L. Vaughn, of Detroit's Psychopathic Clinic, has learned from a study

of boys at the Wayne County Training School.

These boys were from 12 to 15 years old and yet tests showed them to be below grade three in reading. In other words they had spent about nine years in school trying to learn to read without success.

It is hard to realize the insult that such a prolonged failure is to a child. If he can not learn to add, that is to some extent at least a private matter between his teacher, his parents and himself. He can hide those arithmetic papers with the damning zeros.

But when it comes to reading, he is asked to stand up before the whole class and demonstrate almost daily his weakness.

If you have struggled with an income-tax blank, a difficult cross-word puzzle or one of those baffling Oriental cut-up puzzles, you know the exasperation that can result from failure even when no audience jeers at your mistakes.

A child should not be forced to learn to read and to try to master other school subjects until his mind has matured sufficiently to make it possible, is Dr. Vaughn's conclusion.

Teachers should try new methods of instruction with the child who is not learning, or else the child should be given another type of program, such as handwork, that he can master.

No child should be forced to submit to ignominious failure until his whole personality is disorganized, and catastrophe brings him to the psychopathic clinic.

WASHING REMOVES VITAMIN D RAW MATERIAL FROM SKIN

You play a few sets of tennis or toss a medicine ball or take some other kind of vigorous exercise in the sunshine. You come in to the shower feeling full of pep and vitamins. You rub yourself down briskly with a rough towel, and feel even better. But you've lost a good part of the vitamin you have just been acquiring!

For now it appears that the shower and rubdown that are orthodox parts of the American exercise and health ritual actually remove from the skin some of the stuff that vitamin D is made of. This is the conclusion of experiments at the Institutum Divi Thomae in Cincinnati, performed by Agnes C. Helmer and the Reverend Cornelius H. Jansen.

In the experiments, groups of students, after exercising, had their bodies above the waist washed with clear water, which was all carefully saved and evaporated down. The terry cloths with which the students dried themselves were also saved. The residue from the washing and the terry cloths was extracted with ether, and the material thus obtained subjected to ultra-violet irradiation and fed to rats afflicted with rickets.

The defective bones of the rats healed up, showing that the athletes' "washings" had contained the precursor or raw material for vitamin D, which was then converted into the vitamin by the ultra-violet treatment.

In a second experiment the students were first irradiated with ultra-violet and the extracts then made in a similar manner. The results with rats proved that the washing had removed vitamin D itself from the boys' skins.

In their conclusions the experimenters state: "There is definite evidence that the secretions from the skin contain precursors of vitamin D, which after irradiation are due to be reabsorbed by the body, and the removal of which tends to produce a dearth of the vitamin unless it be supplied in some other form."

THE USE OF MAPS IN FIGHTING DISEASE

Most newspaper readers are familiar with the pin- or flag-marked war maps that show the advancing or retreating lines of conflict and other important information on which battle plans are laid. Some of you have doubtless kept such

maps of your own for handy reference when following war news.

Did you know that the great army of health experts which fights to protect us from disease has similar war maps? They hang on the walls of every health department (or should) to give information as to the whereabouts of the enemy and his strength. They are charts showing daily, weekly, monthly and yearly reports of cases of communicable diseases.

The battle lines, marked usually by colored pins, show the advance or retreat of various disease enemies. These lines are called curves. Sometimes, as during epidemics, they are sharply pointed, advancing rapidly to a high peak and usually falling down more slowly to the normal or expected level of cases for that particular disease. The continuous downward sweep of other curves shows the triumph of medical and health science over a particular disease.

Looking over the curve of monthly mortality rate from all causes of death combined, for all ages, Metropolitan Life Insurance Company statisticians find that the enemy has been driven back on one important sector. This consists of the summer months when the death rate formerly ran high chiefly because of "the slaughter of young children by intestinal diseases." Improved sanitary conditions and purer milk and water supplies are the big guns that have broken down the enemy lines on this sector.

The health armies are concentrating now on driving back the enemy lines in the cold season of the year. This means hard fighting against pneumonia, colds, influenza and also on the chronic diseases of heart and kidneys of old people.

STRESS IMPORTANCE OF EARLY DIAGNOSIS IN TUBERCULOSIS

Early diagnosis is half the battle in fighting tuberculosis. When the disease is discovered in its early stages, authorities state, the patient has a good chance for early recovery. The later it is discovered, and the longer the patient puts off starting treatment after diagnosis, the worse his chances get for recovering.

Early diagnosis is important not only for the patient's sake. It is important for protecting his friends and family and the people he works with. Every case of tuberculosis in the infectious stage is a possible source of many more cases. Children are particularly likely to get tuberculosis when some member of the family or household—a servant or boarder or roomer—has the ailment. Once the disease is recognized, however, precaution may be taken to protect children and others in daily contact with the patient.

Recognizing the importance of early diagnosis, the National Tuberculosis Association and local branches throughout the country sponsored an intensive early diagnosis campaign in April. They have urged every one who has any suspicious symptoms which might mean tuberculosis to see a competent physician at once. With a skin test, called the tuberculin test, and with x-ray pictures of the chest, the physician can determine whether or not the patient has tuberculosis. The patient himself, however, must be on guard for the early signs of tuberculosis and take himself promptly to a doctor if he develops any.

The National Tuberculosis Association lists 6 early danger signs of tuberculosis. One is feeling tired all the time when you have nothing to feel tired about. Another is constant loss of weight and strength. If you don't care for food, that's a danger sign. So is a cough that hangs on and on. A pain in the chest that gets worse when you take a long breath is the fifth danger sign. Finally, spitting up blood is a danger sign.

THE SEARCH FOR LONGEVITY[1]

By Professor RAYMOND PEARL
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I

THE available evidence indicates that during the last twenty-four hours something upwards of a sixth of a million fresh new human beings have appeared for the first time upon this earth as a whole. In other words, there has been delivered on our planet to-day well over 600 tons of that strange mixture of water, mineral salts and colloids called human living substance. For delivery this material was neatly wrapped up in a lot of little packets that we call babies. These packets have been turned out to-day at a rate not much below two a second over the whole world. I speak of to-day's activities in the production department of human biology, merely because people like their statistics up to date. But the same sort of thing, in round figures, went on yesterday, and will occur again tomorrow, so we may as well focus attention on to-day's crop as any other.

Each one of these squalling blobs of protoplasm that starts to-day on the journey through time called the life span will endeavor, with all its might and main, to make that journey last just as long as possible. For the will to live, the quest for longevity, is the most deeply rooted and persistent of the biological characteristics of protoplasm organized into individuals. At the beginning of each person's life this urge to survival is wholly unconscious, just a part of living, like digestion or respiration; later on, this underlying protoplasmic will to live, the vital momentum, will be supplemented in the individual by a conscious search for longevity. The great part of to-day's babies who manage to survive until they are somewhere in the twenties will then begin to think a little about what they should do to preserve their health so that they may keep on living longer. Virtually all of them who live until they are seventy years of age or upwards will think about little else from that time on. For it is an odd but profoundly true generalization of human biology that the longer a human being has lived, the more anxious and personally concerned he is, by and large, to keep on living still longer. The octogenarian or nonagenarian may be in wretched health and altogether having a bad time of it, but even so his normal and sound instincts are for keeping on.

Incidentally, it is the almost universal lack of appetite for dying that makes the medical profession a possible one. At the moment, as every one knows, the profession is being wracked with discussions and torn with dissensions over its economics. But if mankind had not, from its remotest antiquity, been profoundly of the opinion that the physician could be of significant help in the struggle to keep on living there would be to-day no question of medical economics to discuss. Physicians are employed, and sometimes are paid, because people fear death and hope to keep on living. And doctors are not the only ones employed and paid for the same reasons. In spite of everything the honest, wise and sincere members of the profession have been able to do, from the time when that arch quack Alexander of Abonutichus and his partner Cocconas practised their deplorable knavery down to the present, a horde of dubious charlatans of all complexions and degrees have fattened off humanity's dis-

[1] Presented as one of the Third Series of "Lectures to the Laity" of the New York Academy of Medicine on February 24, 1938. Published here with the consent of the academy.

taste for dying. It has been revealed to many others besides the unworthy Alexander that, as Lucian said, "human life is under the absolute dominion of two mighty principles, fear and hope." Neither the art nor the science of medicine have as yet, alas, achieved an altogether complete understanding of life or or what to do to prolong it in the individual. The patient sometimes becomes impatient because this is so. Then, so compelling is his survival urge, he turns more often than would happen in a truly rational world to the ministrations of the quacks. Man's reason is evolutionally his most recent acquisition, so perhaps it is not altogether strange that it should be so easily overset by his baser biological instincts.

II

The duration of the journey through life that so many young hopefuls have started upon to-day will vary greatly amongst them. Some of the lot will end it to-morrow, so incomplete is their vital resource and so fragile their design for living. Others, a very few others, of the lot will be living a hundred years from now. The tired eyes of these will have seen many strange happenings in a dizzy world before their journey is done.

The pattern of these varying life journeys and the changes in that pattern in quite recent years are matters of considerable interest and worth looking into on their own account as well as to give us a more solid ground for the further discussion of human longevity. The "order of dying" of a cohort of individuals all born at the same time is given with great accuracy by a device known as the life table, that combines mathematics and biology in a happy and useful mating. For purposes of the present discussion a certain function called the "survivorship" for two life tables has been put in a graphic form, on the supposition that the life journey of which we have been speaking consists in climbing a long and huge ladder. The first of the two life tables chosen for this treatment is one of the latest comprehensive American life tables. It combines into one single well-digested whole the mortality experience of the United States (exclusive of Texas and South Dakota) for the years 1929 to 1931, inclusive. This table was computed and published by Louis I. Dublin and Alfred J. Lotka.[2] The second table to be depicted is that of James W. Glover.[3] based upon the mortality experience of the State of Massachusetts in the year 1890. In both cases we shall deal with the order of dying of white males only. What will be shown is the shape and dimensions of the ladders of life which the respective cohorts of white boy babies —that of 1930 and that of 1890—may be imagined as climbing.

The construction of the ladders is as follows: the total length (or height) of each ladder is the total *span* of life, which is about the same in each case—a little over 100 years. The rungs of the ladder are in each case set ten years of age apart, so that the bottom rung of each is at 10 years of age, the second rung at 20 years, and so on. The length of the rungs—or width or spread of the ladder —is, at each rung, proportional to the numbers of persons in the cohort who live long enough to get a foothold on that rung. Naturally, both ladders are drawn to the same scale in the picture. In both cases 100,000 just-born white male babies

[2] Dublin and Lotka, "Length of Life. A Study of the Life Table." New York: Ronald Press, 1926. Pp. xxii + 400. The life table is on pp. 14–17. The preliminary report of other official United States life tables for 1930, prepared in the Division of Statistical Research of the Bureau of the Census, was published in July, 1936, by Joseph A. Hill (*Vital Statistics—Special Reports*. Vol. I, pp. 389–399). For whites these tables are essentially similar to those given by Dublin and Lotka.

[3] J. W. Glover, United States Life Tables 1890, 1901, 1910 and 1901–1910. Washington (Govt. Printing Office), 1921. The table discussed here is on pp. 132–133.

are supposed to start together climbing the ladder. In the case of the 1929–31 ladder there has been placed opposite each rung a calendar year date. This is meant to suggest that it will be a ladder of life much like the one here depicted that the white American boy babies born to-day will climb. This is not an entirely wild bit of prophecy, because past experience indicates that the ladder they will ascend will almost certainly actually be as good as or better than this one, because it is not likely that medical and public health progress will abruptly stop to-night. It is progress in these two fields in the recent past—within the lives of most of us here to-night—that in large part has wrought the 1929–31 ladder of life into the shape seen in Fig. 1. To be sure other things have been concerned in the matter too—such as improvements in the general conditions of living and of getting a living and in general education—but the forward strides of medical and public health knowledge and practice have surely been the most conspicuous causal elements involved.

It is at once evident that the two ladders, less than half a century apart in time, are quite different in shape. The one for 1930 has an air of broad substantiality—a solid structure that holds a lot of people. The 1890 one stands on the same base, but after the lowest rung is passed becomes a rather narrow, gangling thing, with much less of an air of solid stability; resembling strikingly the sort of ladder built for fruit picking,

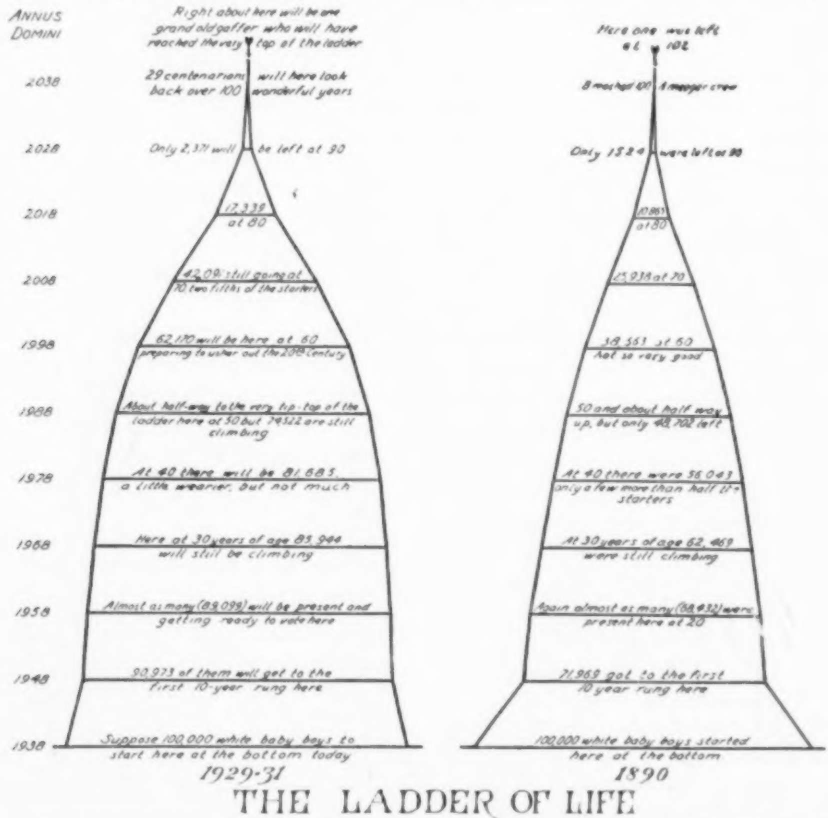


FIG. 1. THE LADDER OF LIFE, AS IT IS SHAPED NOW (ON THE EVIDENCE OF 1929–31), AND AS IT WAS IN 1890, FORTY-EIGHT YEARS AGO. FOR FURTHER EXPLANATION SEE TEXT.

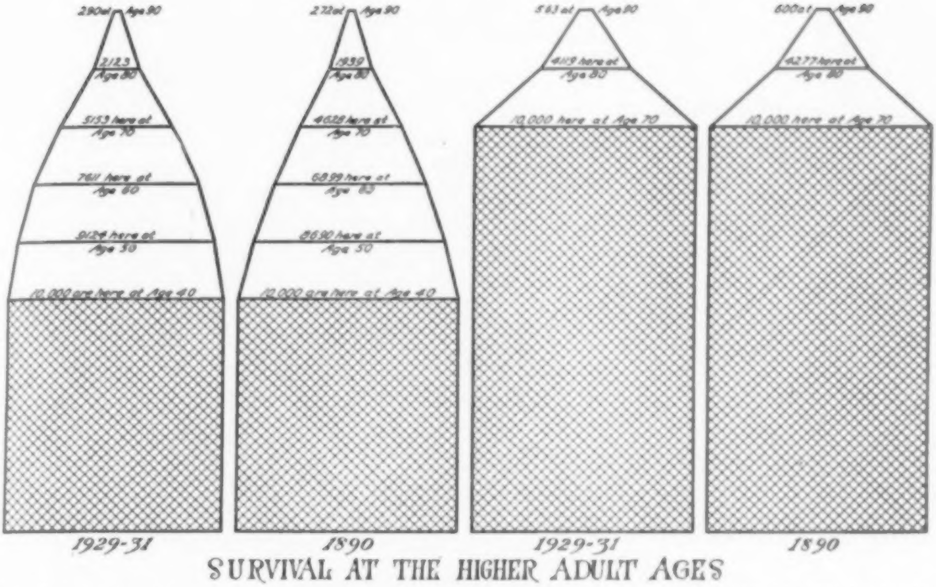


FIG. 2. THE NUMBER OF SURVIVORS AT THE LATER AGES FROM AN EQUAL NUMBER STARTING AT AGE 40 AND AT AGE 70, AS SHOWN BY THE U. S. LIFE TABLE (EXCLUSIVE OF TEXAS AND SOUTH DAKOTA) OF 1929–31, AND THE MASSACHUSETTS LIFE TABLE OF 1890. WHITE MALES.

rather than the broad and heavy firemen's ladders on which human lives depend. At the 50-year rung the 1890 ladder of life accommodated fewer than half the persons who started the climb, while the 1930 ladder at the same point will hold almost three quarters of the starters.

III

In these pictures we see graphically how the prospects for the duration of the journey of life have been altered in the last fifty years or so, and for the better. The improvement has been great, and much credit is due to the medical and public health professions for the part they have played in bringing it about. But the pictures of the ladders do not make it entirely clear just how and wherein the improvement has been made. They give rather a broad general impression of the whole effect. In order to apprehend more clearly a very important, and often overlooked, point about this average improvement in the duration of the individual's life resort must be had to some other pictures, shown here as Fig. 2.

These are pictures of life ladders, too, but of only their upper parts. Suppose we consider what happened subsequently to 10,000 white males who got to the 40-year rung of the 1890 ladder in comparison with 10,000 who will get to the same rung of the 1930 ladder; and then suppose we make the same comparison between 10,000 who got to the 70-year rung of the 1890 ladder and an equal number at the same position on the 1930 ladder.

It is at once evident from Fig. 2 that the duration of the life journey after age 40 for those who have attained that age is, on the average, only slightly longer now than it was in 1890. According to the 1929–31 mortality experience 2.9 per cent. of all those (males) reaching 40 lived to reach 90 years of age. But the 1890 experience shows that 2.7 per cent., or almost as many relatively, did the same then. The gain in the half century for the 40-year-old boys is wholly insignificant in any practical point of view.

Fig. 2 further shows that those who attain the age of 70 now *actually do not do so well relatively,* on the average, in the way of further survival to still higher ages as did the stalwarts of 1890. At that time six hundred out of every 10,000 white males alive at age 70 lived on to 90 or more. Now, on the basis of the 1929–31 experience, only 563 manage this feat.

So it becomes plain that the important achievements in altering the shape of the ladder of life in the last 50 years, have been mainly in regard to the lower rungs. And it is chiefly the lowest or 10-year rung that has been improved. In 1890 only 72 per cent. of the boy babies starting got a foothold on that 10-year rung; now 91 per cent. do. This is splendid and must certainly be warmly approved of by every small boy. But there is extremely little in it to bring cheer to the man at 40 who would like to buy an annuity and look forward to gloating over the issuing insurance company as a nonagenarian.

In the common way of thinking longevity really means living past 80 years, and great human longevity means being a nonagenarian or centenarian. Progress in medicine and improvement in the public health have done little or nothing about enabling the individual to achieve such a goal, as the cold statistical facts about the order of human dying make abundantly clear. The *span* of human life has *not* been lengthened, and there is no present prospect that it soon will be. The *average duration* of life is all that has been altered, and that has been accomplished chiefly by giving more babies a fairer start in life's journey than they used to have. Because more of them get by the early and very difficult hurdles, absolutely more of them survive at later ages. But the terms of the bet that any individual man aged 70 to-day can safely say that he will be alive at 90 appear to be not quite as good as they were 50 years ago.

IV

What Everyman wants to know is whether there is not some sort of biological skullduggery that will, if he only knows what it is, enable him to make a surer and safer bet of this kind. There lies the real problem of the search for longevity. Why is it that some individuals alive at any given age will live thereafter longer than others? This is a biological question, and one of the most fundamental ones that science still has to worry over. In principle the duration of life of any individual is the net resultant of the interplay between his own innate biological make-up and the forces acting upon it, favorable or unfavorable, external and internal. This is a complete and sufficient logical statement of the case, but not so immediately useful as might be wished for the purpose of disappointing eager morticians. The practical searcher for individual longevity is not much interested in logical definitions. He is looking for more tangible help. What can be offered him?

One of the most often quoted things that Oliver Wendell Holmes ever said was that if one is setting out to achieve "three score years and twenty," the first thing to be done, "some years before birth, is to advertise for a couple of parents both belonging to long-lived families. Especially let the mother come of a race in which octogenarians and nonagenarians are very common phenomena." When this statement was made its only foundation was the general impression of a wise physician who spent his own life in a region where octogenarians and nonagenarians were common phenomena. Our practical searcher would like to know the extent or degree to which this impression has been supported by exact, quantitative investigation.

As the first and simplest approach to the question let us consider briefly the analysis of the pedigree of persons who have actually achieved great longevity.

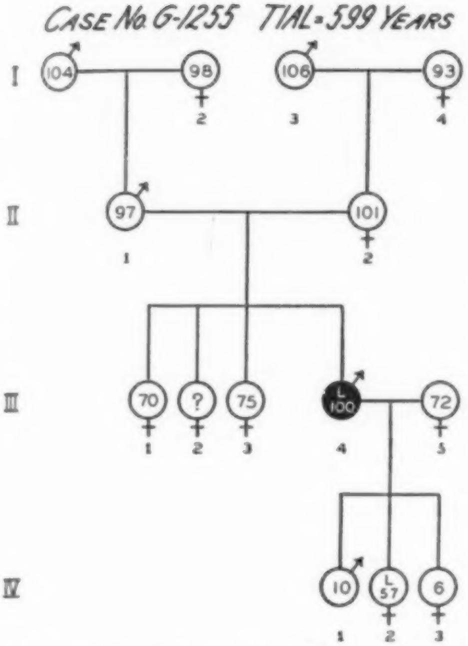


FIG. 3. PEDIGREE OF A CENTENARIAN. IN THIS PEDIGREE THE PERSON UNDER DISCUSSION (THE PROPOSITUS) IS INDICATED BY A SOLID SEX SIGN. FIGURES WITHIN THE CIRCLES OF THE SEX SIGNS INDICATE THE AGES AT DEATH IN YEARS, EXCEPT WHERE THERE IS AN L ABOVE THE AGE FIGURE, WHICH MEANS THAT THE PERSON WAS LIVING AT THE TIME OF RECORD, AND AT THE INDICATED AGE IN YEARS.

For many years we have been collecting data about persons actually living at ages of 90 years and above. The collection now includes more than 2,000 such persons, for whom the personal and family records may be accepted as reliable and trustworthy, after having been thoroughly and critically checked. Many more cases than this have gone through our hands, but have been rejected for scientific study because they did not meet the standards of proof that were set up.

In 1934 my daughter and I[4] published a rather extensive and detailed analysis of 365 of these cases of proven extreme longevity. For each of these cases the ages at death of the six immediate ancestors (two parents and four grandparents) were known and recorded, as well as a great many other things about the person and the ancestors. As an example, the pedigree of one of these highly longevous persons is shown in Fig. 3.

In this case the propositus (III, 4), living at the age of 100, was a Scottish seafaring man, who married and "settled down" at the age of 39. His immediate ancestry is very remarkable in point of longevity. His father (II, 1) and his maternal grandmother (I, 2) died as the result of accidents. His two children (IV, 1 and IV, 3) who died at early ages, met their end by drowning.

At the top of the chart the mysterious word TIAL is merely an abbreviation for "total immediate ancestral longevity," and is used to designate the sum of the ages at death of the parents and grandparents. Thus in the present case 104 + 98 + 106 + 93 + 97 + 101 = 599 years. It is safe to say that few human beings have ever had an authentic TIAL number higher than this.

But how much lower are the TIALS of ordinary people, just "run-of-mine" folk who do not themselves live, on the average, longer than the average of the general population? To get an approximate answer to this question, and to have a group to compare with the highly longevous group of nonagenarians and centenarians we assembled, entirely at random so far as concerned their own ages, a group of 136 living persons all six of whose immediate ancestors (parents and grandparents) were dead at the time of observation, and for each of whom the age at death was known and recorded. This seems as fair a group for comparing TIALS with the longevous group as it is humanly possible to get. This comparison group had an average living age of 48.75 years, and contained 29 persons over 60 at the time of observation, 6 over 70, and 1 over 80. The average age of

[4] R. Pearl and Ruth D. Pearl, "The Ancestry of the Long-Lived." Baltimore and London: Johns Hopkins and Oxford University Presses, 1934. Pp. xiii + 168.

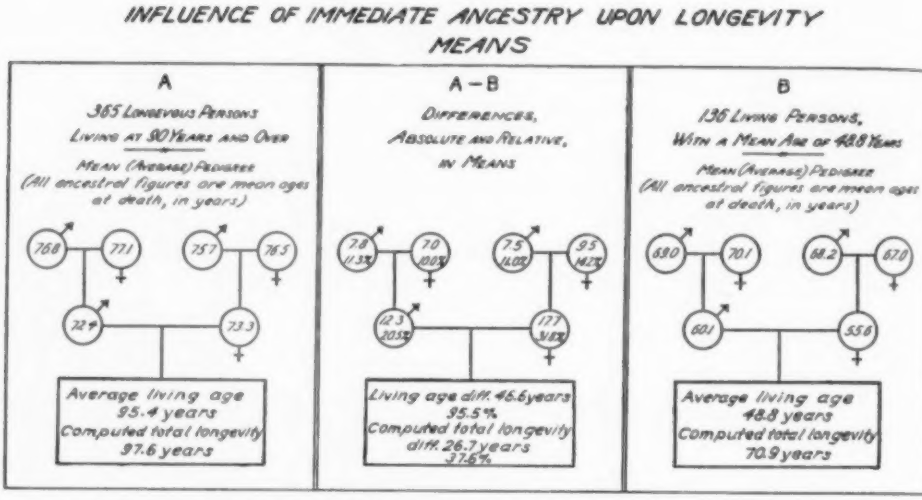


FIG. 4. INFLUENCE OF IMMEDIATE ANCESTORS UPON MEAN (AVERAGE) LONGEVITY.

the group was almost 16 years higher than that of the living white population of the United States in 1930.

How does the ancestral longevity of this group of ordinary folk compare with that of the elite group of extraordinary long-livers, the nonagenarians and centenarians? Fig. 4 gives the answer in graphic form.

From this diagram it is seen that, on the average, each single immediate ancestor, father, mother, grandfather or grandmother, of the extremely longevous persons of panel A on the left side, was longer-lived than the corresponding ancestor of the ordinary persons of panel B on the right side. Thus the fathers of the longevous died at the average age of 72.4 years. This was 12.3 years older, or over 20 per cent., than the average age of the fathers of the panel B folk at the right end of the chart. The central panel, A–B, gives the differences, in absolute numbers of years (upper figures in each sex sign) and as percentages of the panel B means, for each category of the six immediate ancestors. The "computed total longevity" figures for the propositi in the rectangles at the bottom are the resultants of adding to the mean number of years the A and B propositi had already lived at the time of observation the expectations of life proper to those ages, as given in a standard life table.

From this chart two results indubitably emerge regarding the influence of heredity upon longevity, namely:

(a) People who achieve extreme longevity have immediate ancestors (parents and grandparents) who are, on the average, definitely longer lived than the corresponding ancestors of the general run of the population. This is true without exception for each particular category of immediate ancestors.

(b) This hereditary influence promoting longevity is between two and three times as great relatively for parents as it is for grandparents, so far as the results of this investigation indicate.

It appears, then, that old Dr. Holmes was sound in his advice to select long-lived parents, and particularly long-lived mothers.

Let us now go a little deeper into the matter, by proceeding to examine more specifically how each of the *parents* of the extremely longevous persons was bred relative to longevity, as compared with the parents of the general run of folk. For the purposes of this inquiry let us

regard an individual who dies under 50 years of age as short-lived; one who dies between 50 and 69 years as average or mediocre in life duration, and one who dies at 70 or over as long-lived. These ranges in general agree fairly with common-sense opinion and usage. Fig. 5 shows the percentages of the fathers and mothers respectively that had (a) both of *their* parents long-lived (shown by the solid black portion of each bar); (b) one parent long-lived and the other mediocre or short-lived (shown by the cross-hatched portion of each bar); and (c) neither of their parents long-lived (shown by the white portion of each bar).

The picture presented by Fig. 5 is precise and striking. The nonagenarians and centenarians were produced by parents who were themselves bred out of wholly longevous parentage in more than half of all the cases observed—a markedly higher proportion than that shown by the parents of the general population sample. At the other end of the genetic scale the opposite is true. Fewer than half as many proportionally of the nonagenarians and centenarians as of persons generally were produced by parents who themselves had no longevous parentage whatever. It seems clear beyond question or doubt that breeding counted mightily in the production of these nonagenarians and centenarians.

Let us now turn to another method of approach, and a wholly different material, to get still another view of the importance of inheritance in the quest for longevity. Suppose one were to go out and collect entirely at random every single case possible to find of children dying before they were five years old—extremely short-lived human beings in fact, who were unable to get far in the pleasant business of living either because they were inherently bad biological eggs literally or figuratively, or because they never had a fair chance to live on account of a bad environment associated with parental poverty or ignorance or vice. Now suppose further that we followed the fathers of these poor creatures

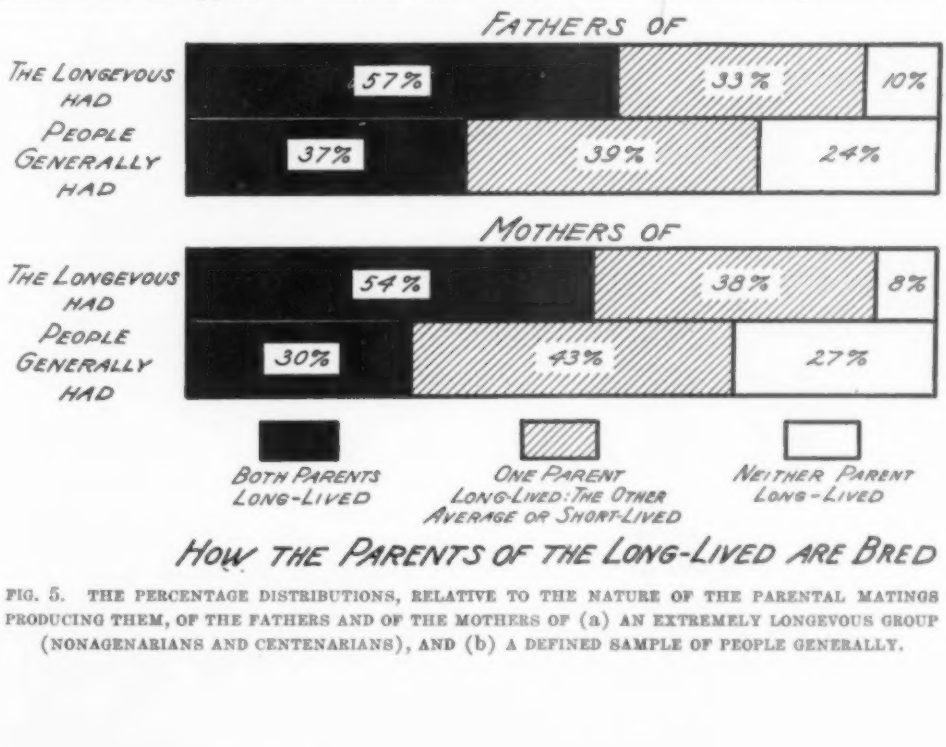


FIG. 5. THE PERCENTAGE DISTRIBUTIONS, RELATIVE TO THE NATURE OF THE PARENTAL MATINGS PRODUCING THEM, OF THE FATHERS AND OF THE MOTHERS OF (a) AN EXTREMELY LONGEVOUS GROUP (NONAGENARIANS AND CENTENARIANS), AND (b) A DEFINED SAMPLE OF PEOPLE GENERALLY.

along through their whole lives and set down in the record their ages at death when they (the fathers) finally died. It would then be possible to construct a life table for the category of *Fathers of Persons Dying under 5 Years of Age.* Having done all this, suppose we next did precisely the same thing for a group of fathers of persons who did not die until they were 80 years old or more—in other words, a group of old gaffers with demonstrated great powers of living, which powers may conceivably have arisen from their innately superior biological make-up or from great good luck combined with good sense in their choice of victuals and drink, or from always wearing their rubbers when it rained and woolies when it was cold, and so on through the entire list of precepts and superstitions thought to promote lon-

FIG. 6. EXPECTATION OF LIFE IN YEARS (MEAN-AFTER-LIFETIME) AT AGES 20, 40, 60, AND 80, OF FATHERS OF CHILDREN DYING (a) UNDER 5 YEARS OF AGE (SOLID BARS) AND (b) 80 AND OVER YEARS OF AGE (CROSS-HATCHED BARS).

FIG. 7. LIKE FIG. 6, BUT FOR MOTHERS.

gevity. When the data had been collected and the computations made we should then be in possession of a life table for the category of *Fathers of Persons Dying at 80 and Over Years of Age.*[5]

How will these two life tables compare with each other? Fig. 6 shows the answer so far as concerns the expectation of life (or average-after-lifetime) at four selected ages 20, 40, 60 and 80 years.

It is at once evident that, so far as concerns the present material involving well over a hundred thousand life years' exposure to risk, the long-lived children had fathers who were much longer-lived than the fathers of short-lived children. The figures at the tops of the bars give the expectations of life at the ages indi-

[5] For details regarding the construction of these and the life tables to be discussed below see R. Pearl, "Studies on Human Longevity. IV. The Inheritance of Longevity." *Human Biology*, 3: 245–269, 1931.

cated at the bottoms of the bars. Thus the average *total* duration of life from birth of the fathers of children dying at ages of 80 and over was $58.5 + 20 = 78.5$ years.

Corresponding life tables for mothers tell the same sort of story, as is shown in Fig. 7.

The *relative* excess in life duration of the parents of long-lived as compared with short-lived children is very considerable. Thus the mean-after-lifetime of *fathers* of children dying (or living) at ages of 80 and over is about 26 per cent. greater at age 20; 43 per cent. greater at age 40; 75 per cent. greater at age 60; and 58 per cent. greater at age 80, than the mean-after-lifetime at the same ages of fathers of children dying under 5. The corresponding excesses

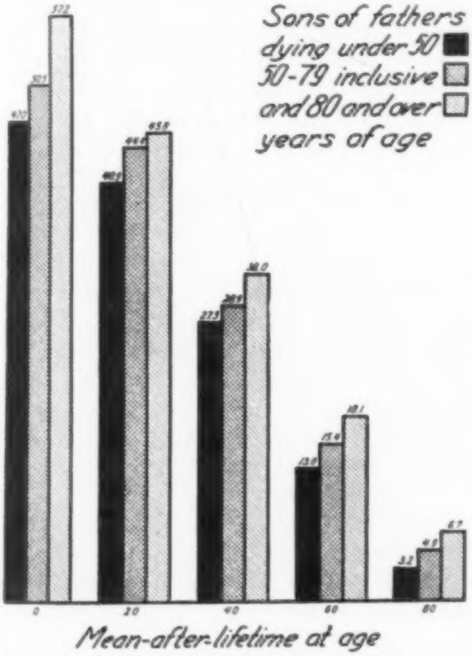


FIG. 8. EXPECTATION OF LIFE IN YEARS (MEAN-AFTER-LIFETIME) AT AGES 0 (BIRTH), 20, 40, 60, AND 80 YEARS, OF THE *sons* OF FATHERS DYING (a) UNDER 50 YEARS OF AGE (SOLID BARS); (b) BETWEEN 50 AND 79 YEARS OF AGE (DOUBLE CROSS-HATCHED BARS); AND (c) 80 AND OVER YEARS OF AGE (SINGLE CROSS-HATCHED BARS).

in expectation of life of mothers are 27 per cent. at age 20; 27 per cent. at age 40; 36 per cent. at age 60; and 23 per cent. at age 80. The suggestion plainly is that right away through the whole life span the parents of very long-lived children appear to be persons of superior biological constitution, as evidenced by their ability to keep on living.

What now of the situation turned the other way about? How will the respective life tables compare if we construct them for the *children* of short-lived, moderately long-lived and very long-lived parents? This we have done for *sons* as a class, with the results shown in Fig. 8.

Plainly the results of these life tables for sons confirm the conclusions derived from those for fathers and mothers that have just been examined. As we pass upwards through the three broad classes of paternal longevity the expectation of life of the sons at all ages steadily rises. The expectation of life of the sons of short-lived fathers is less than that of the sons of moderately longevous fathers, and still less than that of the sons of extremely long-lived fathers. Thus at age 60 the sons of very long-lived fathers (80 and over) have a further average expectation of life nearly 40 per cent. greater than that of sons whose fathers died before age 50.

It seems unnecessary to present further evidence to demonstrate the great significance of genetic factors in determining individual differences in the length of human life. The inherited biological constitution of each individual human being—his or her genetically determined inherent viability—is beyond question one of the major determiners of the probable length of that person's life. It is not, however, the sole or absolute determiner. Obviously any one can behave in such a way that his or her genetic birthright in longevity is prevented from coming to its full expression. Prematurely taking one's own life is per-

haps the most nearly perfect example. On the other hand, the general effect of public health and sanitary measures is to create and promote such conditions of living as will permit the greatest possible number of people to bring as nearly as possible to complete realization and expression the inherent viability with which they have been genetically endowed. In the changing shapes of the Ladder of Life shown earlier it has been seen how great the progress has been in this respect for the earlier years, and how little for the later years of the life span. This suggests, in the light of the evidence regarding the inheritance factors in longevity, two conclusions that may be of considerable significance. The first is that there exist broad classes of human beings differentiated from each other in their innate endowments in respect of inherent viability, one class being short and the other being long of this important quality. The second suggested conclusion is that improving the environmental circumstances of living can do, and has done, a great deal more for the first class than for the second in the way of increased longevity. It appears probable that there is now, and always has been in past ages, a class of human beings by nature so abundantly endowed in the matter of viability that they have always, as a statistical group, so nearly realized their innate potential viability regardless of environmental circumstances as to be not significantly affected in average duration of life by any general improvement of those circumstances.

Detailed study of the life histories of extremely longevous persons, such as has been possible with our collection of such records, strongly suggests that nonagenarians and centenarians are biologically differentiated from the general run of mankind in just the manner postulated for the second biological class just described. As a group nonagenarians and centenarians have definitely *not* led protected lives in specially favorable environmental circumstances; nor have they had better medical advice or care than the generality of men; nor, finally have they conducted their lives more hygienically than others, according to the rules and precepts generally regarded as conducive to long life. On the contrary they have just lived, but lived a much longer time than most.

This view of the matter is further supported by an analysis of the causes of death of nonagenarians, made some years ago on the basis of the official records of the Census Bureau.[6] That analysis led to the conclusion that nonagenarians are a selected lot of people. They are the ultimate survivors after all the rest of mankind has gone, unable to meet the vicissitudes of life and keep on living. Nonagenarians come to be such because they have organically superior constitutions, resistant to infections, soundly organized to function efficiently as a whole organism and keep on doing it for a very long time. Observations on mortality at ages indicate that throughout life infections and other harmful environmental forces are, on the whole, tending to take off the weaker and leave the stronger. Medical knowledge and skill, improved sanitation and better conditions of life generally have been and are, able to prevent an increasingly larger amount of what may be called premature mortality before age 50, let us say. Especially have these agencies been able to reduce the lethal effects of infections, or at least to postpone to a later part of the life span their fatal action. But ultimately there is left a group of extremely old people, for whom on the whole infections have no particular terrors. In all the early part of their lives they have been able successfully to resist infections, and to a remarkable degree still are in extreme old age.

[6] R. Pearl and T. Raenkham, "Studies on Human Longevity. V. Constitutional Factors in Mortality at Advanced Ages." *Human Biology*, Vol. 4, pp. 80–118, 1932.

These people eventually die, to be sure. But a great many of them die, not because the noxious forces of the environment kill them, but because their vital machinery literally breaks down, and particularly that important part of it—the circulatory system.

V

Evidence has been presented indicating that genetic factors are important in determining individual longevity. It has further been suggested that these genetic influences manifest themselves in relation to longevity primarily through the general biological constitution of the individual, so far as can be judged in the basis of present knowledge regarding this complex and difficult problem.

There will now be presented for the first time, in necessarily condensed form, some results of an investigation now in progress that appear to throw additional light on the problem of constitution in relation to longevity. The problem attacked may be put in this way: Suppose that one were able to make fairly thorough and complete studies, medical, anthropometric and genetic, of adult persons in a state of health at the time of observation, then follow them individually till they died, and then finally determine and record the causes of their deaths individually. Would it then be possible to isolate and differentiate any characteristics exhibited at the time of original observation years before, from which could have been predicted *then* who were destined to be the long-lived and who the short-lived, had the original observer been as wise before the event as afterwards? In other words, is it possible by any sort of examination or study of healthy adult individuals to predict which ones are destined for a long subsequent life and which will exhibit no marked powers of further survival?

At the expense of considerable time and labor records have been collected upon this question, and some of them have been analyzed. In particular we have studied rather thoroughly 386 white males from this point of view. These individuals were originally observed and recorded at ages ranging from 20 to over 60 years; 193 of them proved in the event to be long-lived, in the sense that each one of them outlived in greater or smaller degree the expectation of life (mean-after-lifetime) for his age when observed, according to Dublin and Lotka's 1929–31 life tables already referred to above. All white males in our records fulfilling this condition of survivorship greater than that expected from the life table were taken for study without any selection. Then as a partner for each one of these 193 long-lived males there was taken from the record a white male of the same decade of age, who died *before* reaching the expected degree of survivorship proper to his age as set forth in the Dublin and Lotka life tables. All these 386 persons died in the end of some form of cardiovascular disease—that is of heart disease in one or another of its forms or of some affection of the arteries or veins.

So then in sum, what we have are two groups of white males of the same age distribution and in a state of health at the time of observation, all of whom died of diseases characterized by structural or functional breakdown or inadequacy of the circulatory system. One of these groups was definitely longer-lived than the average of American men at the present time, while the other group was definitely shorter-lived than the average. In what respects, if any, did the two groups differ from one another before either displayed any discernible evidence of cardiovascular disease? Table 1 and Fig. 9 give the more important aspects of the answer to this question.

Considering Part A of the table it is seen that while the two groups were substantially *identical* in average age at observation (approximately 40 years) the

long-lived group lived thereafter more than 26 years or over 52 per cent. *longer* than did the short-lived group. The actual survival of the first group was 123 per cent. of life table expectation, while that of the second group was only about 35 per cent. of life table expectation.

At the time of observation the average pulse rate per minute was, by an absolutely small but statistically significant amount *slower* in those destined for long life than in those who were to live less than a third as long a time. Furthermore the long-lived group exhibited at observation an average systolic blood pressure slightly over 2 per cent. *higher* than did the short-lived group, a difference that is, however, statistically insignificant. The average blood pressure in both groups, it will be noted, was well within what is regarded as the clinically normal range for persons of an average age of about 40 years. But the number in the long-lived group for which blood pressure readings were available was very small (27 cases only), so that altogether the findings relative to blood pressure depend upon only 54 individuals in total. A satisfactory appraisal of the situation relative to blood pressure differences between long-lived and short-lived groups will have to wait on the slow accumulation of additional data.

In physical characteristics of the body (Part B) the two groups were of substantially *identical* average stature, but

TABLE 1

CONSTITUTIONAL DIFFERENCES BETWEEN LONG-LIVED AND SHORT-LIVED WHITE MALES WHEN OBSERVED IN A STATE OF HEALTH PRIOR TO THE ONSET OF THE CARDIOVASCULAR DISEASES THAT EVENTUALLY LED TO DEATH

Part A. Age and physiological characteristics

Cause of death, group and differences	Mean (average) value of characteristic					
	Age at observation (yrs.)	Age at death (yrs.)	Actual survival (yrs.)	Percentage of expected survival (yrs.)	Pulse rate (per minute)	Systolic blood pressure
Long-lived ($N = 193$) ..	40.09	76.59	36.49	123.45	73.45	133.89
Short-lived ($N = 193$) ..	39.56	50.27	10.69	35.45	74.62	131.22
Difference	+0.53 ± .71	+26.32 ± .50	+25.80 ± .63	....	−1.17 ± .29	+2.67 ± 1.74
Difference as per cent. of short-lived mean..	+1.34	+52.36	+241.35	....	−1.57	+2.03

Part B. Somatological characteristics

Cause of death, group and differences	Mean (average) value of characteristic						
	Stature (cm)	Body weight (kg)	Body weight ratio (kg)	Chest girth at expiration (cm)	Chest expansion (cm)	Umbilical girth (cm)	Habitus index (%)
Long-lived ($N = 193$) ..	173.80	70.27	4.04	86.62	9.06	85.05	98.77
Short-lived ($N = 193$) ..	174.09	74.56	4.28	89.51	9.55	86.47	101.09
Difference	−0.29 ± .43	−4.29 ± .68	−0.24	−2.89 ± .48	−0.47 ± .21	−1.42 ± .62	−2.32
Difference as per cent. of short-lived mean	−0.17	−5.75	−5.60	−3.23	−5.13	−1.64	....

Part C. Genetic data

Cause of death, group and differences	Mean (average) value of characteristic					
	Percentage of parents living at time of observation	Percentage of sibship living at time of observation	Percentage of total sibship dying in infancy	Per cent. of all parents and sibs dead of cardiovascular diseases	Per cent. of all parents and sibs dead of respiratory diseases	Per cent. of all parents and sibs dead of diseases of alimentary tract
Long-lived ($N = 193$) ..	48.96	73.71	9.15	3.00	5.33	3.43
Short-lived ($N = 193$) ..	41.58	80.56	5.72	4.92	4.37	2.98
Difference	+7.38	−6.84	+3.43	−1.92	+0.96	+0.45

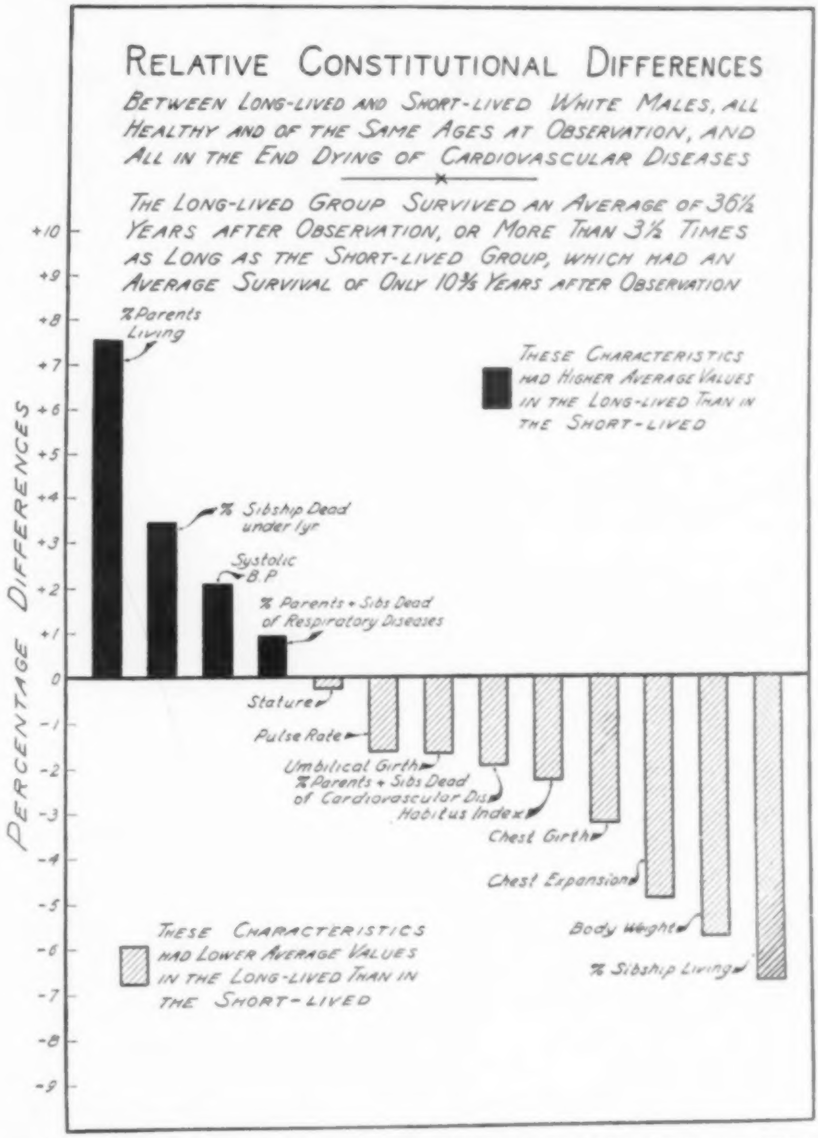


FIG. 9. SOME RELATIVE DIFFERENCES IN CONSTITUTION BETWEEN LONG-LIVED AND SHORT-LIVED WHITE MALES. FOR FURTHER DESCRIPTION SEE TEXT.

the long-lived group *weighed*, on the average, nearly 6 per cent. *less* than the short-lived group, again a statistically significant difference. Furthermore the long-lived averaged to be *smaller* in chest girth (at expiration) and in girth at the level of the navel (umbilical girth) than the short-lived. Also, as shown by the habitus index,[7] the long-lived group on the average was *less* of the pyknic type in body build than the short-lived group —in other words the long-livers tended to be more like Don Quixote and the short-livers more like Sancho Panza in their bodily structure.

The long-lived group had over 7 per cent. *more*, on the average, of their parents alive at the time of observation than did the short-lived group, indicating a sounder inheritance in respect of longevity. On the other hand, *fewer* of the brothers and sisters of the long-lived, on the average, were still living when the observations were made, than was the case with the short-lived. This suggests that natural selection had operated more stringently in the sibships containing the long-lived persons, an interpretation that is supported by the higher infant mortality rate that had manifested itself in the sibships of the long-lived. Finally, and more specifically from the genetic side, the long-lived group, had *fewer* proportionately of their parents and sibs dead of cardiovascular diseases at the time of observation than did the short-lived.

Fig. 9 sums up graphically some of the results of this constitutional study.

In general it appears, so far as may be judged from the present sample, that there is a definite possibility that long-lived persons as a group can be statistically differentiated from short-lived persons in respect of a number of structural, physiological, and genetic characteristics, long before they are going to die and while they are still in sound health. It would be unwise to generalize much further than this at present. More work needs to be done, and we propose to continue doing it just as rapidly and extensively as can be managed. It is a laborious and expensive sort of research, and the resources available to us for its support are so meager that progress is distressingly slow. But the results already achieved seem clearly to indicate that we have opened up here a line of approach to the problems of human longevity that gives promise of eventually yielding results of considerable significance, both theoretical and practical. We have made similar analyses to the one here presented for two smaller groups of long-lived and short-lived persons dying respectively of cancer and pneumonia, with extremely suggestive results; but the cases available are still too small to warrant even preliminary publication at present.

VI

Up to this point the discussion has ben almost entirely of the innate, constitutional elements concerned in the determination of individual life duration. It is now time that some attention be devoted to the environmental aspects of the picture. Here is where the eager searcher for longevity finds his greatest interest. For while he will admit that in an academic or philosophical point of view it is doubtless desirable to know as much as possible about the hereditary and constitutional factors influencing life duration, still these are after all not matters about which he can do much in the way of promoting his own personal longevity. "Choosing one's parents" is a sufficiently amusing figure of speech, but really nothing much more than that.

[7] Habitus index =

$$\frac{100\ (\text{Chest girth at expiration} + \text{Umbilical girth})}{\text{Stature}}$$

This somatological index, which appears not to have been used hitherto, is proving to be a very useful one in classifying variation in bodily habitus (Kretschmerian typology). The asthenic type of body build leads to a relatively low index, and the pyknic type to a relatively high one. It is intended to publish soon in another place a detailed discussion of this index.

What our searcher really wants is to be able to do something effective right here and now about a matter of such transcendent personal concern. He would like to be authoritatively told how he should conduct his life so to live long. Still better he would like to be provided with some pleasant pill or potion guaranteed to keep him going until he reaches ninety at least, without any bother about what he eats or drinks in the meantime, or whether he bundles up well when he goes out in the cold. Best of all he would like to be supplied with some of the authentic juice that flows from the Fountain of Perpetual Youth. Since mankind started making literary records of his thoughts and aspirations the search for that elusive spring has been earnestly prosecuted. Many people have figured out just what it would look like when it was found. One of the most charming and delightful of its many portrayals serves as the frontispiece of a rather rare book that is one of the gems of an extensive collection of tracts and treatises dealing with longevity down through the ages. The title page of this book is shown in facsimile in Fig. 10. The frontispiece depicting the Fountain of Perpetual Youth, with its surrounding landscape is shown in Fig. 11.

HISTOIRE
DES PERSONNES
QUI ONT VECU
PLUSIEURS SIECLES,
ET QUI ONT RAJEUNI:
AVEC LE SECRET
DU RAJEUNISSEMENT,
Tiré d'Arnauld de Villeneuve.
Et des Régles pour se conserver en santé, & pour parvenir à un grand âge.
Par Mr. DE LONGEVILLE HARCOUET.

A PARIS,
Chez la Veuve CARPENTIER, & LAURENT LE COMTE. 1716.
AVEC APPROBATION ET PRIVILEGE.

Se vend A BRUXELLES,
Chez JEAN LEONARD, Libraire & Imprimeur rue de la Cour.

FIG. 10. FACSIMILE OF THE TITLE PAGE OF HARCOUET'S *Histoire*.

FIG. 11. FACSIMILE OF THE FRONTISPIECE OF HARCOUET'S *Histoire*, DEPICTING THE FOUNTAIN OF YOUTH. ORIGINAL SIZE OF ENGRAVED AREA 110 × 66 MM.

One notes the triumphant and smug satisfaction with which his conductor is telling the weary and sceptical old physician in the lower left foreground, who may be Aesculapius himself: "There, you doubting old fuddy-duddy, I said it was here, and *here it is!* See for yourself!" In the right foreground is evident the almost obscene eagerness of the old boys just arrived to guzzle the precious fluid gushing from the fountain, while the bloated saurian leers up at them and gets his share. In the distant background we get a glimpse of the garden in which so much of humanity as was there remained perpetually youthful, until the lady unfortunately committed a technical error. The fauna of the environs of the fountain is characteristically reptilian. Of the four Orders of the Class Reptilia three are represented—the *Loricata* (Crocodiles and Alligators), the *Chelonia* (Tortoises and Turtles), and the *Squamata* (Lizards and Snakes). The only Order omitted is the *Rhyncocephalia*, which contains only one form, the famous *Tuatera* found in the islands of Cook Strait, New Zealand. This seems an excusable omission, because New Zealand has always been so far away from the center of things. It will also be noted that an elephant is emerging from the trees in the background. This is to round out the lesson of the picture as a whole; because, of all mammals except man, the elephant is the longest lived. The Reptilia of course have always been noted for longevity. The banner borne by the two Rocs at the top of the picture is an anachronism, plainly put in as a sop to conservative respectability. For if we really had access to the Fountain of Perpetual Youth who would worry about health?

Unfortunately it has proved impossible to get a supply of water from the Fountain of Youth to distribute on this occasion. Lacking this the best that can be done is to discuss some of the environmental factors that have been thought to be, or in fact are, importantly concerned in the achievement of longevity. Only those will be chosen for discussion about which there exists definite scientific evidence, pertinent to the point at issue.

Of all such factors the use of alcoholic beverages has probably been most discussed. The problem of the effect of such usage upon longevity has excited violent and unreasoning prejudice on the part of large numbers of people. They contend that alcohol always and everywhere shortens the lives of its users. There is much evidence, experimental, statistical and actuarial that this is not a universally valid generalization. This evidence does not make the slightest impression upon those who believe, that is to say *have faith*, that the generalization is valid. So an *impasse* results. So far as I am aware there has been constructed only once a set of life tables for classes of persons homogeneous in respect of

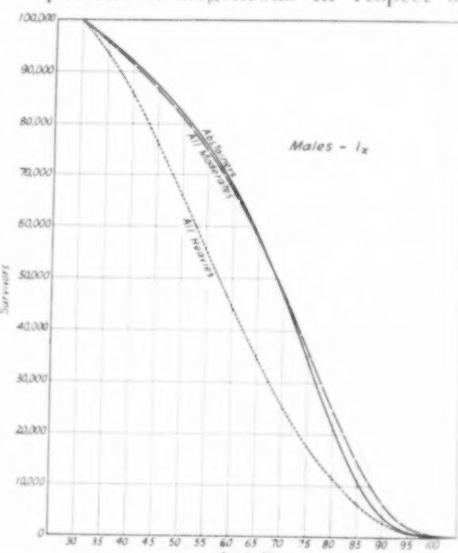


FIG. 12. THE NUMBER OF SURVIVING MALES OUT OF 100,000 STARTING TOGETHER AT AGE 30, IN THREE DRINKING CATEGORIES: (a) ABSTAINERS (SOLID LINE), (b) MODERATE DRINKERS (DASH LINE), AND (c) HEAVY DRINKERS (DOT LINE).

TABLE 2

THE NUMBER OF SURVIVORS, AT 5-YEAR AGE INTERVALS STARTING AT AGE 30, OF (a) 100,000 WHITE MALES WHO WERE NON-USERS OF TOBACCO; (b) 100,000 WHO WERE MODERATE SMOKERS BUT DID NOT CHEW TOBACCO OR TAKE SNUFF; AND (c) 100,000 WHO WERE HEAVY SMOKERS BUT DID NOT CHEW OR TAKE SNUFF

Age	Number of Survivors l_x						
	Non-users	Moderate	Heavy	Age	Non-users	Moderate	Heavy
30	100,000	100,000	100,000	65	57,018	52,082	38,328
35	95,883	95,804	90,943	70	45,919	41,431	39,393
40	91,546	90,883	81,191	75	33,767	30,455	22,338
45	86,730	85,129	71,665	80	21,737	19,945	14,494
50	81,160	78,436	62,699	85	11,597	10,987	7,865
55	74,538	70,712	54,277	90	4,573	4,686	3,292
60	66,564	61,911	46,226	95	1,320	1,366	938

their habits relative to alcoholic indulgence, and based upon critically adequate and pertinent data collected at first hand.[8] Those life tables lead to the general conclusion graphically depicted in Fig. 12.

That conclusion is that moderate drinking does not significantly shorten life when compared with total abstention from alcohol, while heavy drinking does seriously diminish the length of life.

These results have been accepted by some, and rejected by other equally sincere, equally honest and intelligent groups of people, who however differ widely in their emotions and sentiments regarding the use of alcohol by man as a beverage. Nothing further can be done about the case. Presumably each one of the present audience is already a component of one or the other of these two groups.

Let us turn next to the use of tobacco and longevity. This usage is probably, along with that of alcohol, one of the most wide-spread amongst humanity relative to substances or materials that are not, in themselves, necessary to the maintenance of life as is food. Is the smoking of tobacco associated statistically with any impairment of the normal expectation of life, or with an improvement of it, or is there no measurable association one way or the other? This question, too, has excited controversy, though not so violent as that over alcohol. It is the intention to present now for the first time a small part of the hitherto unpublished results of an investigation of this problem.[9] This investigation, like the preceding one on alcohol, has been carried out with painstaking care, and such critical acumen, judgment and fairness as my collaborators and I possess. The data were collected at first hand *ad hoc*. Their accuracy as to the relative degree of habitual usage of tobacco, and as to the ages of the living at risk, and of the dead at death can be guaranteed. The figures to be presented deal only with white males, and with the usage of tobacco by smoking. The material falls into three categories, as follows: *non-users* of tobacco, of whom there were 2,094; *moderate smokers*, of whom there were 2,814; and *heavy smokers*, of whom there were 1,905. In other words, the results presented here are based upon the observation of 6,813 men in total. These are not large numbers from an actuarial point of view, but are sufficient to be probably indicative of the trends that would be shown by more ample material. Naturally the men included in the observation were an unselected lot except as to their tobacco habits. That is to say they were at random, and then all sorted into categories relative to tobacco usage. For each of the three categories of tobacco usage complete life tables from

[8] R. Pearl, "Alcohol and Longevity." New York: Alfred A. Knopf, 1926. Pp. xii + 273.

[9] Since this lecture was delivered there has been published a further account of these life tables. R. Pearl, "Tobacco Smoking and Longevity," *Science*, 87: 216–217, 1938.

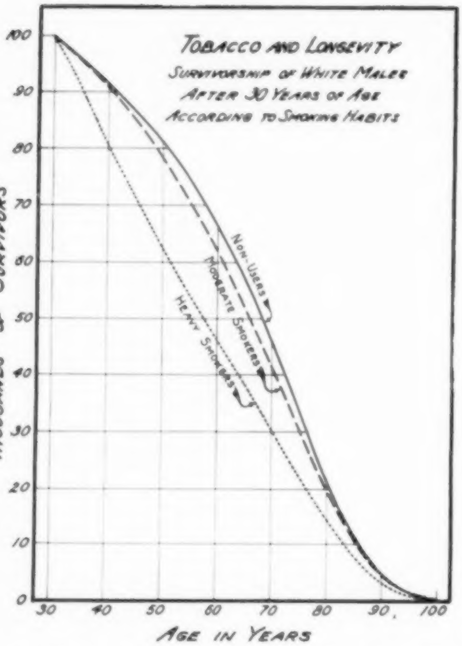


FIG. 13. THE SURVIVORSHIP LINES OF LIFE TABLES FOR WHITE MALES FALLING INTO THREE CATEGORIES RELATIVE TO THE USAGE OF TOBACCO. A. NON-USERS (SOLID LINE); B. MODERATE SMOKERS (DASH LINE); C. HEAVY SMOKERS (DOT LINE).

age 30 on to the end of the life span have been constructed.

It is intended to publish eventually in detail the results of this investigation. Here there can be presented only a condensed table, which gives the survivorship (l_x) values, at 5-year intervals from age 30 on, for the three usage categories.

The figures of Table 2 are shown graphically in Fig. 13.

The net result is obvious. In this group of nearly 7,000 men the smoking of tobacco was associated definitely with an impairment of life duration, and the amount or degree of this impairment increased as the habitual amount of smoking increased. The contrast between the life tables relative to the implied effects upon longevity of moderate smoking, on the one hand, and the moderate use of alcoholic beverages, on the other hand, is very striking. The moderate smokers in this material are definitely shorter lived than the total abstainers from tobacco; the moderate drinkers are not significantly worse or better off in respect of longevity than the total abstainers from alcohol. Heavy indulgence in either tobacco or alcohol is associated with a very poor life table, but the life table for heavy smokers is definitely worse than that for heavy drinkers up to about age 60. Thereafter to the end of the life span the heavy smokers do a relatively better job of surviving than the heavy drinkers. But neither group has anything to boast about in the matter of longevity.

The third environmental problem to be discussed may be put in this way: Does hard physical labor shorten life? The answer to this question is shown graphically in Figs. 14 and 15.

The data[10] on which Figs. 14 and 15 are based come from English occupational mortality statistics which are as accurate and comprehensive as any in existence. The results indicate that there is a direct and definite relation between the magnitude of the age specific death rates from age 40 to 45 on, and the average expenditure of physical energy in occupation, *after* accidental deaths and deaths directly resulting from the hazards of each of the several occupations have been deducted. This relation is of the sort that associates high mortality with hard physical labor. The relationship prevails whether the labor is performed chiefly indoors or chiefly outdoors. It is not primarily to be attributed to the general environmental factors connoted by social class distinctions, which are themselves correlated with average energy expenditure in occupation. Before age 40 is attained, it makes no difference in the rate of mor-

[10] See R. Pearl, "Studies in Human Longevity." Baltimore: Williams and Wilkins, 1924, Chapter XI, for a detailed account of this study.

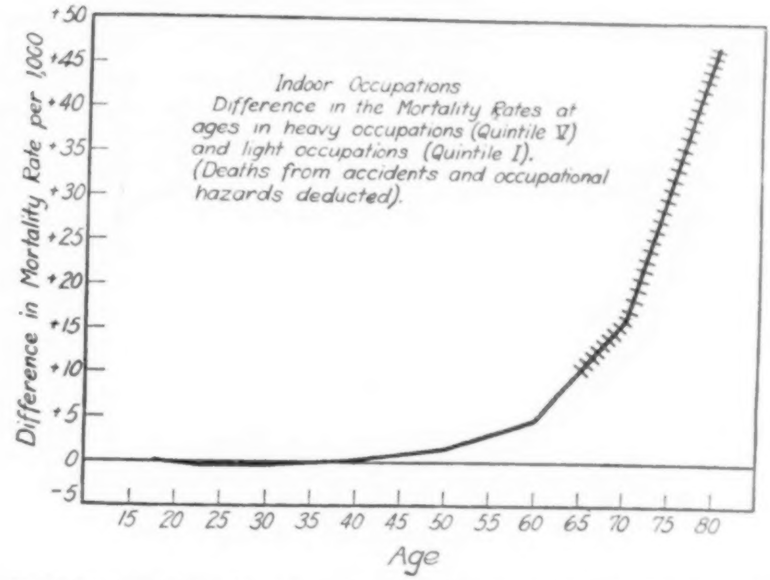


FIG. 14. DIFFERENCE BETWEEN (a) INDOOR OCCUPATIONS INVOLVING THE GREATEST AMOUNT OF PHYSICAL EXERTION (QUINTILE V) AND (b) INDOOR OCCUPATIONS INVOLVING THE LEAST AMOUNT OF PHYSICAL EXERTION (QUINTILE I), IN RESPECT OF AGE SPECIFIC MORTALITY RATES. THE LINE IS CROSSED FROM AGE 65 ON TO INDICATE THAT ITS TRUE POSITION IS UNCERTAIN AT ADVANCED AGES, BECAUSE OF THE MEAGERNESS OF THE DATA AVAILABLE.

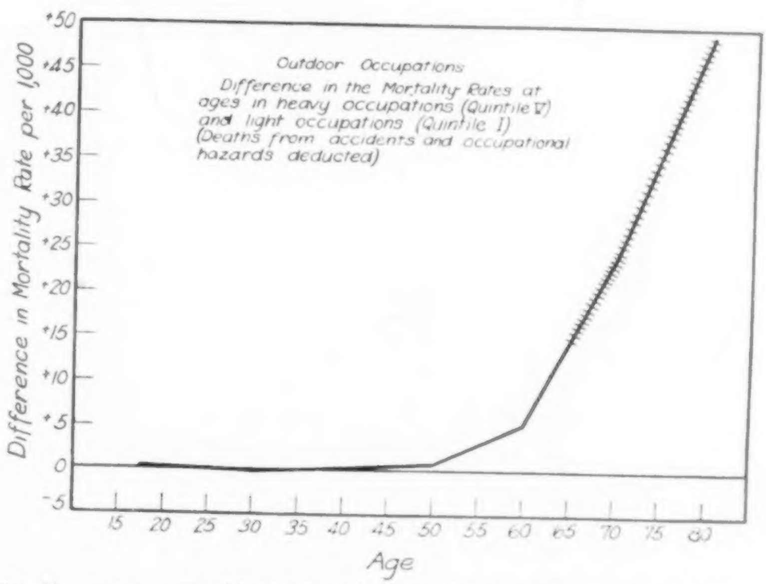


FIG. 15. SAME AS FIG. 14, EXCEPT THAT IT DEALS WITH OUTDOOR OCCUPATIONS.

tality whether the occupation involves light or heavy physical labor. After roughly age 40 to 45 it appears that a man shortens his life, by definite amounts, in proportion as he performs physically heavy labor.

VII

As the termination of this discourse is now near at hand, it is evident that nothing at all has been said about many aspects of the problem of human longevity. These omissions are not to be regarded as consequences of any lack of interest or intrinsic importance in some of the omitted topics. It is mainly a consequence of that profoundly significant fact that an hour includes only sixty minutes.

But certain omissions have been deliberate and from principle. Much might have been said regarding various theories and speculations about the duration of life that have been put forward in increasing number in recent years. Mostly these have come, directly or indirectly, from consideration of the results of experimental work with lower forms of life. Much of this work has been of fine quality and great intrinsic interest and importance to biology as a science. Some of these experiments have led to highly spectacular success in absolute or relative prolongation of life. For example it has been possible to manipulate seedlings in such a manner as to make them live more than *seven times* as long as they normally would on a given supply of energy and matter as resources for living.[11] Partial or intermittent starvation of various lower animals has led to similar results in the hands of various workers. There is, however, at the present time no smallest reason or justification for even suggesting that results of this sort, and various other sorts in comparable status, have any application whatsoever to human longevity. To insinuate, as some have done in calculated newspaper publicity, that results of this sort might lead in the near future to a startling extension of the human life span is only a bit of naive professorial *Reclam*. When just one single life has been provably prolonged by the application of any such principle its discoverer will not need to advertise. The medical profession will know all about it, and will be testing its possibilities for further extension.

Again it will have been noted that no advice has been given this evening about how to conduct life so to live long. The reason for this omission is simple. I am not a medical man. It is the proper professional business of medical men to instruct and advise people about healthy and continued living. They have done well at it, and their collective wisdom about it waxes day by day. On the other hand, detached observation suggests that when laymen take on the job, as all too many of them love to do, the results have not been quite universally all that could be desired. Some conspicuous examples could be cited by way of illustration of this point, without having to wander very far geographically. The truth is, as every physician knows, that human life and living are extremely complicated matters, not amenable to simplification by formula or to amelioration by panacea. Really helpful advice about unravelling these complications will come only from the wisdom that grows out of experience and knowledge. The purity of heart and nobility of purpose of bustling "do-gooders" or the ready omniscience of gentry eminent in branches of science *other* than medicine are poor surrogates for the real knowledge and wisdom of the seasoned medical practitioner in the search for longevity.

The literature of longevity is full of advice, recipes and precepts for the attainment of long life. These precepts touch upon nearly every conceivable as-

[11] S. A. Gould, R. Pearl, T. I. Edwards and J. R. Miner, *Annals of Botany*, 48: 575–599, 1934.

pect of personal physiology and hygiene. Yet it is an odd fact that careful study of our collection of life records of nonagenarians and centenarians leads, as one of the broadest generalizations it is possible to make from them, to the conclusion that these 2,000 and more persons exhibited substantially the same range and degree of variation relative to these various items of personal hygiene as is found amongst people in general. Some were light eaters, others on the gluttonous side; some used tobacco, others didn't; some drank heavily, others were teetotalers; some slept a lot, others didn't; some had been in robust health all their lives; others had been ailing a great part of the time; and so on. In only one outstanding respect besides great longevity did the group markedly differ from the generality of mankind, on the whole. That is the fact that a vast majority of these extremely longevous folk were of a placid temperament, not given to worry. They had taken life at an even, unhurried pace. In this respect this human material agrees with and confirms a generalization that has emerged from experimental studies on life duration. It is that *the length of life is generally in inverse proportion to the rate of living.* The more rapid the pace of living is, the shorter the time that life endures. This relationship has been shown to exist for a variety of forms, including plants, various lower animals, insects and men.[12] It is a relation that is obviously in some degree within the power of individual, personal control.

The search for longevity is not ended, though this discourse is. In the view of the biologist the search has only just got well under way. A great deal more will be learned, and just possibly we may find out how to lengthen significantly and at will the span of human life, instead of merely increasing its average duration. But if and when this happens the biologist and medical man will probably need to call for the help of the sociologist, the economist and the philosopher to fix over the world, so that it will be better suited for old people to live in than it now is.

[12] For a general discussion of this topic see R. Pearl, "The Rate of Living." New York: Alfred Knopf, 1928. Pp. 185.

BENJAMIN FRANKLIN

THE FINAL MODEL OF THE HEROIC STATUE NOW BEING SCULPTURED BY JAMES EARLE FRASER, WHICH IS TO BE UNVEILED IN FRANKLIN HALL OF THE FRANKLIN INSTITUTE, BENJAMIN FRANKLIN PARKWAY, PHILADELPHIA. THE STATUE WILL BE OF WHITE "SERAVEZZA" MARBLE, APPROXIMATELY TWICE LIFE-SIZE. WHEN ERECTED UPON ITS PEDESTAL IN FRANKLIN HALL, IT WILL RISE TO A HEIGHT OF 18 FEET ABOVE THE FLOOR.

THE PROGRESS OF SCIENCE

THE MEMORIAL TO BENJAMIN FRANKLIN

As it was so often during his life, the name of Benjamin Franklin will be "on the tip of the tongue" in scientific and educational circles during the latter part of May of this year when a new national shrine will de dedicated to the memory of the great natural philosopher and American patriarch in Philadelphia, the city where Franklin sought a successful career as a printer, and found not only that but also subsequent world-renown in the fields of science and statesmanship.

President Roosevelt has expressed his intention of unveiling on May 19 a heroic white marble statue of Franklin in a stately memorial room in the Franklin Institute, on Philadelphia's Benjamin Franklin Parkway. The statue is the work of the noted American sculptor, James Earle Fraser.

The memorial room, known as Franklin Hall, will be the spiritual center of the classic structure which houses the Wonderland of Science museum and the Fels Planetarium of the Franklin Institute. Constructed entirely of marble of different varieties, the hall will be bare of any adornment other than the heroic statue and its own architectural charms. It is octagonal in shape and 82 feet in length, width and height.

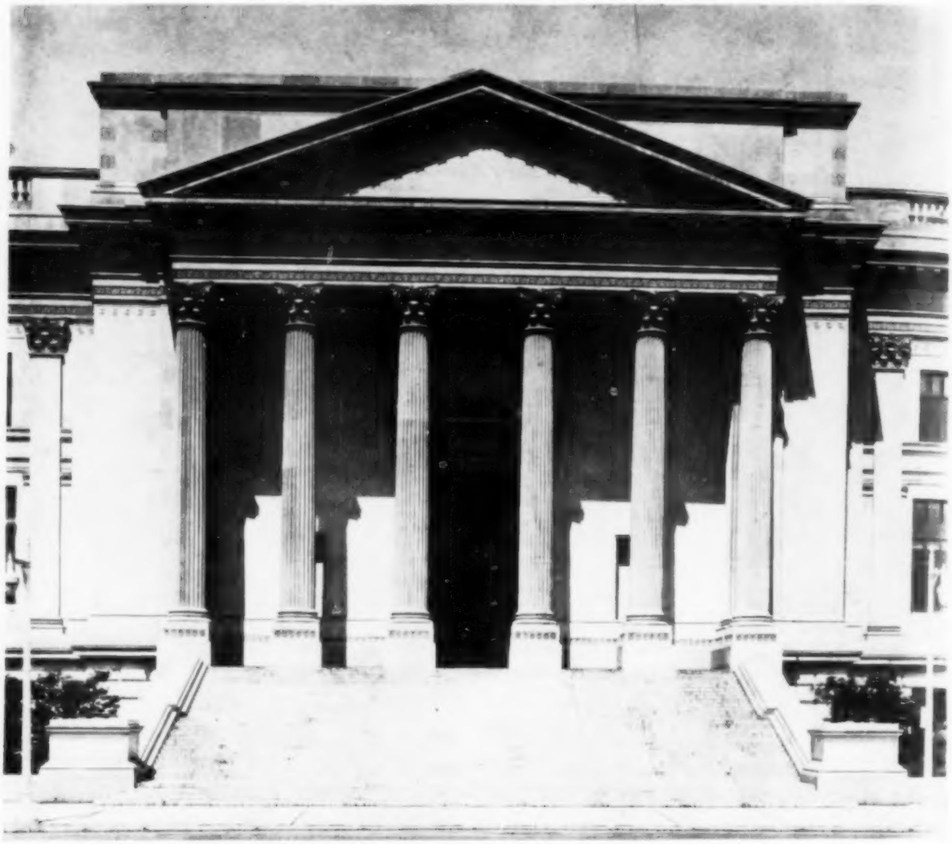
When erected upon its massive pedestal of Rose Aurora marble from Portugal, the statue will rise to a height of 18 feet above the floor. It will be a seated figure of Franklin, approximately twice life size. The combined weight of pedestal and statue will be 120 tons.

Franklin Hall will be the scene of memorable events during the dedication. Following the unveiling ceremony, diplomatic representatives of France and Britain and the Canadian Minister will honor the statue by placing wreaths at its foot. In the evening of May 20, the University of Pennsylvania, founded by Benjamin Franklin, will confer degrees there, and the Franklin Institute will award medals.

"Many-sided" is a term often applied to Franklin; which is not remarkable when it is recalled that he was noted as a printer, author, public-spirited and philanthropic citizen, natural philosopher, inventor, statesman and diplomat; and further, that as a natural philosopher, his interests and achievements were not confined to one branch of science, but practically ran the gamut of the fields of scientific learning of his day, including aeronautics, agriculture, astronomy, botany, chemistry, electricity, geology, hydrostatics, hygiene, mathematics, medicine, meteorology, navigation, oceanography, optics, orthography, paleontology and physics. This was borne in mind in planning the program for the three days of dedicatory exercises by a large organization of prominent Philadelphians, headed by Mr. Philip C. Staples, president of the Franklin Institute; the Honorable George Wharton Pepper, honorary chairman; and Dr. Henry Butler Allen, secretary and director of the Franklin Institute, general chairman.

The first day, May 19, will honor "Franklin, Patriot and Man"; the second day, May 20, "Franklin, Philosopher and Educator"; and the third day, May 21, "Franklin, Printer and Business Man." Furthermore, the second day will be featured by a notable educational and scientific gathering, at which different branches of pure science will be discussed.

This meeting, which will be held in the lecture hall, where each season the Franklin Institute presents for its members the scientific lectures for which it has been noted since its inception 114 years ago, will be addressed by eminent scientists and educators of two conti-



THE FRANKLIN INSTITUTE

PORTALS OF THE FRANKLIN INSTITUTE BEARING THE INSCRIPTION "IN HONOR OF BENJAMIN FRANKLIN." THIS ENTRANCE LEADS DIRECTLY TO THE FRANKLIN MEMORIAL AND ITS HEROIC STATUE OF FRANKLIN.

nents. That it will be a meeting such as Franklin himself would revel in, were he alive, is evident from the list of those who have accepted invitations to present papers on various pure sciences.

It will be gratifying to admirers of Benjamin Franklin that the head of a world-renowned Parisian medical society of the present day—Dr. Louis Martin, director of the Pasteur Institute—will come to the United States to be one of the speakers in the pure science meeting. Although not a medical doctor, Franklin became a man of note in the medical world and was elected a member of the Royal Medical Society of Paris and the Medical Society of London. His fame in this respect was nowhere greater than in Paris, where he represented the American colonies with such signal success during the Revolutionary War. The King of France appointed him a member of a commission to investigate the claims of Anton Friedrich Mesmer as to "animal magnetism," and it was Franklin who drew up the report exposing Mesmer.

Another who will come from abroad to pay tribute to Franklin will be Sir James Colquhoun Irvine, principal and vice chancellor of Saint Andrews University, Aberdeen, Scotland. It was at

Saint Andrews that the first of his numerous honorary degrees was conferred upon Benjamin Franklin. Others who will present papers are Dr. George D. Birkhoff, mathematician of Harvard University; Arthur L. Day, director of the Geophysical Laboratory at the Carnegie Institution, Washington, D. C.; Dr. Merritt L. Fernald, botanist, Harvard University; Dr. Gilbert N. Lewis, dean of the college of chemistry, University of California; Dr. C. E. K. Mees, director, research laboratory, Eastman Kodak Company, Rochester, N. Y.; and Dr. Thomas H. Morgan, zoologist, of the California Institute of Technology. Presiding will be Dr. E. G. Conklin, executive vice president of the American Philosophical Society, which was founded by Benjamin Franklin and of which he was president for many years.

Representatives of engineering and professional societies will attend another meeting to be held in the lecture hall on May 21, which will be devoted to applied science. Dr. Harvey N. Davis, president of the Stevens Institute of Technology, Hoboken, N. J.; Dr. Willis R. Whitney, vice-president in charge of research of the General Electric Company, Schenectady, N. Y.; Dr. W. E. Wickenden, president of the Case School of Applied Science, Cleveland, Ohio; and Mr. Abel Wolman, chief engineer, State Department of Health, Baltimore, Md., will be the speakers. Mr. Leonard T. Beale, president of the Pennsylvania Sale Manufacturing Company, will preside. In the evening a banquet will be held at which the Honorable Herbert C. Hoover will give the principal address.

The Franklin Institute is securing many special exhibitions which will be added to the 4,000 action displays in its Wonderland of Science museum during the dedication and the weeks to follow. This distinctive museum has sections devoted to astronomy, aviation, the graphic arts, chemistry, medicine, marine transportation, music, electrical communications, illuminating engineering, railroad engineering, physics, fire fighting and prevention, materials of construction, prime movers and mechanisms; also a seismograph and a large observatory. Last year the Wonderland of Science and the Fels Planetarium attracted more than half a million visitors. This year, because of the interest that will center upon the dedication, it is expected that these numbers will be greatly increased.

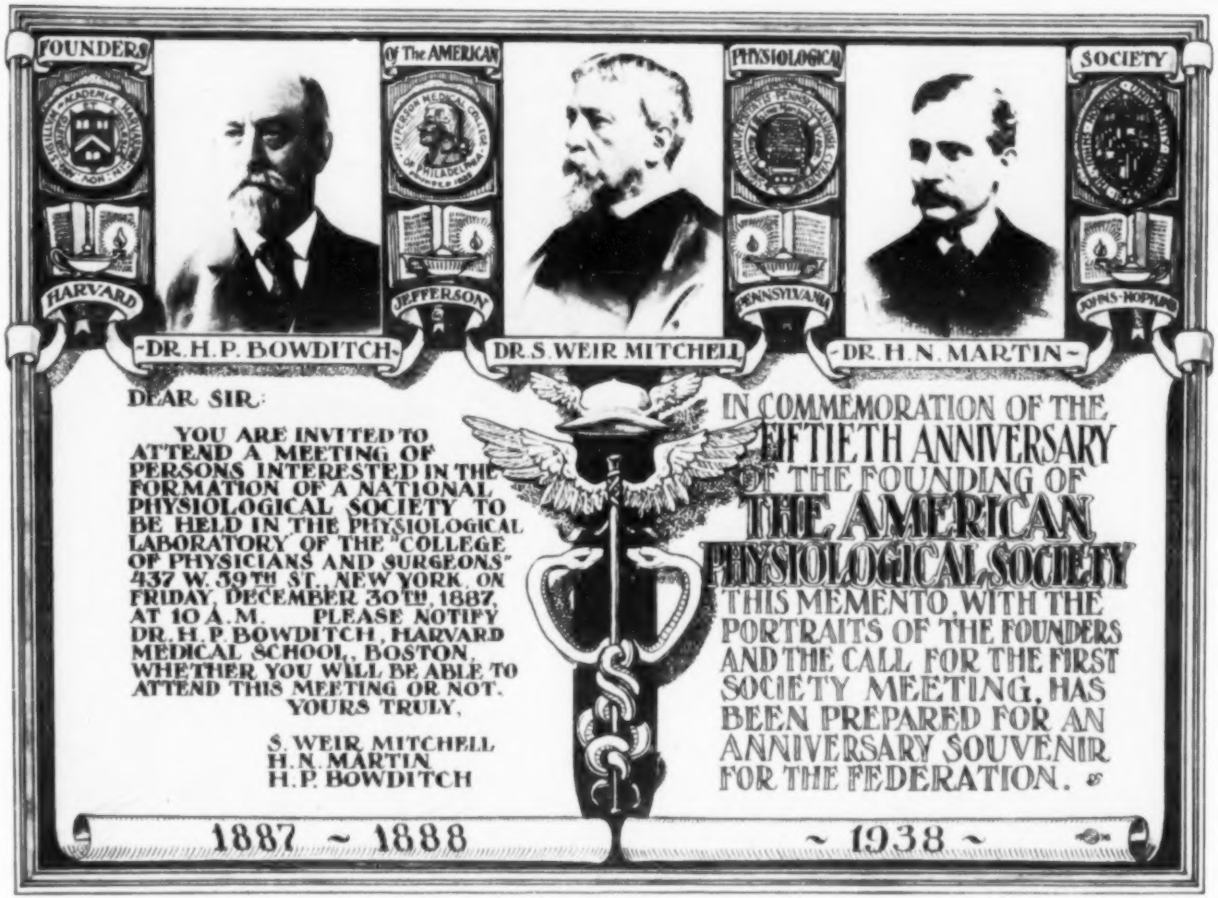
The new Benjamin Franklin Memorial, perpetuating through the arts the memory of Franklin, the man, in this stronghold of science and mechanics, to which Franklin, the natural philosopher, contributed so notably, will honor one of the greatest of Americans with one of the world's outstanding mementos of a life of distinguished achievement.—C. L. J.

THE FIFTIETH ANNIVERSARY OF THE AMERICAN PHYSIOLOGICAL SOCIETY

The three great events in the history of American physiology have been the development of the experimental laboratory, the establishment of the *American Journal of Physiology* and the organization of the American Physiological Society. This year the society celebrated the fiftieth anniversary of its founding.

The celebration took the form of a special program at the recent annual federation banquet and the preparation of a history of the society.

At the banquet four of the five living original members were present as guests of honor: Professor R. H. Chittenden, emeritus professor of physiological chemistry at Yale, Professor William H. Howell, emeritus professor of physiology at Johns Hopkins, Professor Joseph Jastrow, former professor of psychology



MEMENTO PRESENTED TO MEMBERS OF THE AMERICAN PHYSIOLOGICAL SOCIETY ON THE OCCASION OF ITS FIFTIETH ANNIVERSARY CELEBRATION

at Wisconsin and Professor W. P. Lombard, emeritus professor of physiology at Michigan. Dr. F. W. Ellis, Monson, Massachusetts, the fifth, was unable to be present. For the occasion Dr. W. T. Porter, the founder and first editor of the society's journal, was made honorary president of the society and acted as toastmaster. Dr. J. J. Abel, emeritus professor of pharmacology at Johns Hopkins University, was a distinguished guest. Dr. W. H. Newton brought the greetings from the British Physiological Society, and Dr. C. H. Best represented the Canadian Physiological Society.

The program itself consisted of the roll call of the organization members by President Walter E. Garrey, the introduction of the original members present and eulogies of the three founders; H. P. Bowditch, by Walter B. Cannon; H. Newell Martin, by Dr. W. H. Howell, and Dr. S. Weir Mitchell, by Dr. A. J. Carlson.

The American Physiological Society was actually founded on Friday, December 30, 1887, the organization meeting being held in the physiological laboratory of the College of Physicians and Surgeons, 437 West 59th Street, in New York City. The call for the meeting was a small mimeographed slip signed by S. Weir Mitchell, H. N. Martin and H. P. Bowditch. It is probable that the idea of forming a society originated with Dr. Mitchell, but certainly Dr. Martin, who was an original member of the British Physiological Society, was also responsible, particularly for the constitution and early policies. Seventeen were present at the organization meeting and eleven more were made members, a total of twenty-eight. The membership included practically all the biological scientists of the day who were using the experimental physiological method. Besides the founders themselves the list included such celebrities as John C. Dalton, then president of the College of Physicians and Surgeons, J. G. Curtis, S. Stanley Hall, Wm. Osler, V. C. Vaughan and Wm. H. Welch.

A "History of the Physiological Society from 1887 to 1937" was one of the undertakings sponsored by the semicentennial committee. The first twenty-five years of this story has been written by Dr. William H. Howell, an original member, an early president and one closely associated with the society throughout its career. To Dr. Charles W. Green, long an efficient secretary and recently president, has fallen the lot to write of the period of growth which has taken place during the last twenty-five years.

In the growth of an organization comparisons are of interest. At the first annual meeting of the American Physiological Society thirteen members were present and five papers were presented. At the fiftieth annual meeting the members present were in the hundreds and the total number of papers and demonstrations was 422. For the first twenty-five years one session each half day was enough to take care of all those wishing to make reports. At the fiftieth annual session five sections were continuously in action. As a matter of fact these statements cover only a small part of the society's growth, for from its membership three separate societies have now been segmented. In 1906 the American Society of Biological Chemists was formed; the Society for Pharmacology and Experimental Therapeutics appeared in 1908 and the Pathological Society in 1913. These separations after all were for matters of convenience and made no difference in the intimacy of the group, for they were at once organized into one general organization, the Federation of Societies for Experimental Biology and Medicine. The first meeting then of the Physiological Society with its attendance of thirteen and five papers should really be compared with the 1938

federation meeting with its attendance of over 2,200 and 745 papers.

In the period of fifty years certain trends may be noted. The tendency toward greater specialization has always been apparent. Sections devoted to circulation, respiration, electrophysiology and endocrines are practically separate society meetings. The type of research has often closely followed the development of special methods. The use of the x-ray, sensitive galvanometer and the amplification tube has greatly increased research possibilities. Demonstrations, at first the public performance of some new experiment, have now been crowded out for want of space, and this year "static demonstrations" were employed. Free discussion, a characteristic of the early days, has been somewhat revived by the multiplicity of sections. At first the meeting place was invariably the laboratory of some medical school, but now the largest hotel, auditorium or armory is necessary to accommodate the membership. Throughout the years two characteristics have, however, remained unchanged, and on these the success of the organization has always rested. Membership has always depended on a continuance of activity in physiological research, and there has always been the warmest of welcomes extended to scientific youth.

The American Physiological Society from its foundation has been an important factor in the scientific life of our country. It is a forum in which are presented the current researches in the physiological sciences. It is the owner and manager of two great journals. It is the mother of societies. Not only has its past been honorable and productive, but at the present moment it is more prosperous in point of members and scientific activity than at any period of its history.

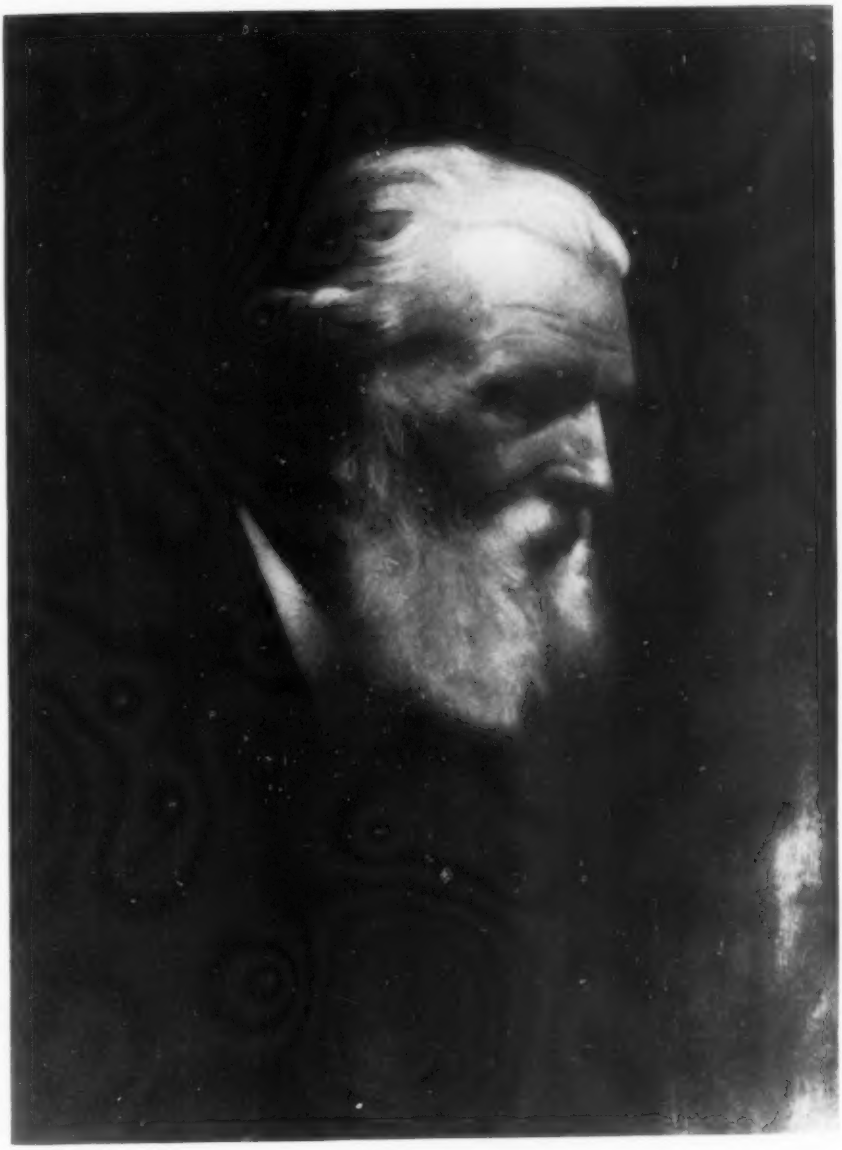
WALTER J. MEEK,
Chairman of the Semi-centennial Meeting
UNIVERSITY OF WISCONSIN

JOHN MUIR AND THE NATIONAL MONUMENT IN HIS HONOR

THE one-hundredth anniversary of the birth of John Muir, conservationist and explorer, occurred on April 21, 1938. He was born of Scottish parents in Dunbar, Scotland, where he lived the first ten years of his life. When Muir was eleven years of age his father emigrated to America, taking up a homestead in Wisconsin, then a frontier wilderness. In his early twenties Muir attended the University of Wisconsin, but, characteristic of his independence of thought, he did not follow a formal course of study but chose his own courses, which were mainly chemistry, geology and, later, botany. This independence was evidenced again, in later years, when he refused the chairs offered him by Harvard University and the Massachusetts Institute of Technology. He felt that such academic preeminence would not compensate for the loss of his freedom to roam the wilds.

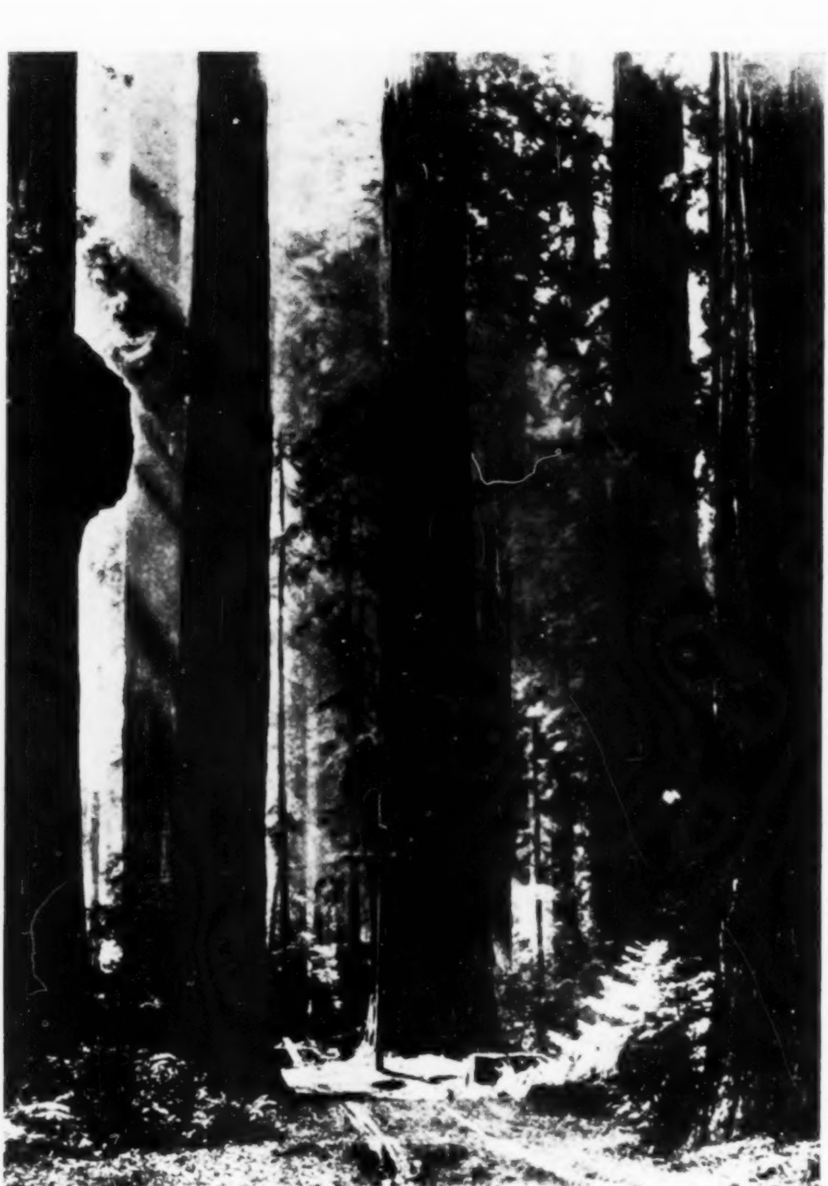
John Muir, though at first interested in applying himself to a mechanical trade, was a wanderer nearly all his life. He was injured while working in an Indianapolis factory and as a result of the accident lost the sight of one eye. Soon after his recovery he set out on a thousand-mile trip to the Gulf of Mexico. Long afterward his notes were published as "A Thousand Mile Walk to the Gulf." These notes are valuable because of the picture they present of the attitude of that period on the subject of conservation.

From Florida he went to Cuba, took passage to New York and from New York sailed, steerage, around Cape Horn to California. For a decade he made his principal abode the valley of the Yosemite, and from there made many expeditions into the High Sierra. He explored mountain and glacier and studied their



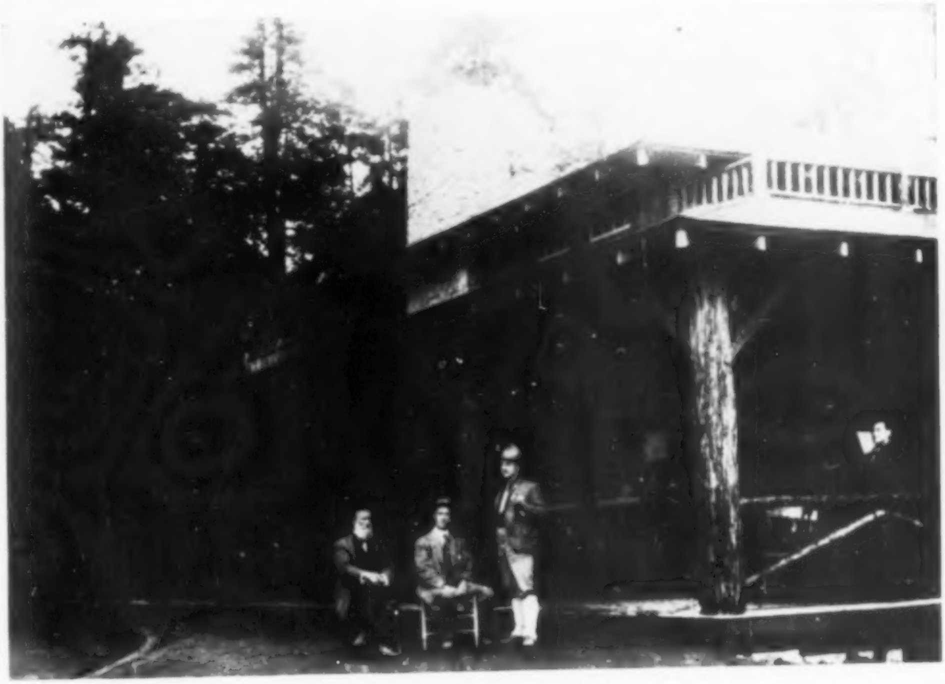
JOHN MUIR

PHOTOGRAPHED FROM THE PAINTING BY HERBERT A. COLLINS, A STAFF ARTIST OF THE WESTERN MUSEUM LABORATORIES OF THE NATIONAL PARK SERVICE OF THE DEPARTMENT OF THE INTERIOR. THIS PICTURE IS ON EXHIBITION IN THE MUSEUM AT THE MUIR WOODS NATIONAL MONUMENT.



REDWOODS IN THE MUIR WOODS NATIONAL MONUMENT

geologic past. His first published works were the series, "Sierra Studies." To-day he is remembered in the name of "The John Muir Trail," which extends from Yosemite to Mount Whitney. But Muir's travels were not confined to the West and South. His first trip to Alaska was made in 1879. At that time he discovered Glacier Bay and the great glacier which bears his name. Muir also period. Muir frequently left the Alhambra Valley on trips of exploration and in 1889 conducted Robert Underwood Johnson, one of the editors of the *Century Magazine*, into the Yosemite. This trip had far-reaching effects, for it led to the Muir-Johnson conservation movement, for which both labored for the rest of their lives. Legislation was passed in 1890 which established Yosem-



OLD MUIR WOODS INN

SHOWING, LEFT TO RIGHT, JOHN MUIR, WILLIAM KENT (DONOR OF MUIR WOODS NATIONAL MONUMENT) AND GIFFORD PINCHOT. PICTURE TAKEN ABOUT 1913. THE INN HAS SINCE BEEN DESTROYED BY FIRE.

explored the upper reaches of the Yukon and McKenzie rivers and in 1890 journeyed through the Caucasus, Siberia, Manchuria, Japan, India, Egypt, Austria and New Zealand.

When he was forty-two Muir married the daughter of one of the most successful horticulturists in California. He rented part of his father-in-law's holdings and became a successful fruit raiser and was able to retire within a ten-year ite National Park, Sequoia and General Grant National Parks.

William Kent presented to the nation the grove of redwoods near San Francisco with the understanding that the tract should bear the name of the man who saved so many trees from destruction. The Muir Woods National Monument was created by presidential proclamation on January 9, 1908. It contains 427 acres and is situated at the foot of

Mount Tamalpais, in southern Marin County, not far from the city of San Francisco.

Many trees in the Muir Woods grove are centuries old, yet the Redwood does not reach the extreme age commonly accredited it. Often the Big Tree of the Sierra and the Redwood of the coast are confused. Both are Sequoias, but separate and distinct species, the Redwood being scientifically named *Sequoia sempervirens* and the Big Tree, *Sequoia gigantea*. The Redwood is found only along the coast and is the species which grows the tallest of any tree in the world, now reaching the extreme height of 364 feet. It seldom exceeds a diameter of 20 feet or an age of 2,000 years. The Big Tree grows only on the western slope of the southern Sierra Nevadas and attains an age of 4,000 years or more and a diameter of over 35 feet. Long ago fire ran through the grove at Muir Woods and left in its wake charred stumps and deep fire scars in the butts of living trees. Circles of mature trees surround fire-killed stumps whose roots sent up and fed these now mature trees shortly after fire had killed the parent tree. The fire scars, weathered by time, add to the picturesqueness of the scene.

In addition to its natural beauty, the woods is noted for abnormal growths, such as burls, albino shoots and fasciated formations on Redwoods, while interesting natural grafts and peculiarities are found on other trees. Burls range in size from those sold in florists' shops to huge ones six or more feet in diameter. Large root burls appear to be bowlders embracing the foot of the tree, while smaller burls occur in a variety of sizes and shapes upon the trunks. Various other trees are abundant throughout the woods and contribute their part to the Redwood forest type. California laurel, tan bark oak and Douglas fir are plentiful, while madrone alder, nutmeg and buckeye are found scattered through the grove. In Fern Canyon a Douglas fir 8 feet in diameter has been dedicated to the memory of the late William Kent.

Multitudes of flowers and ferns are found growing throughout the woods, and during the spring and early summer their blossoms add to the grace, charm and solemnity of the Redwoods. Wildlife abounds within the monument. Deer wander up and down the forest aisles at dawn and dusk. Raccoons are plentiful and bobcat, fox, coyote, skunk and mountain lion are occasionally seen. Birds are also numerous, but the majority of them spend their time in the tall tree tops and are not apparent to the average visitor. Fry and fingerlings of salmon and steelhead trout swarm in countless numbers in the larger pools, and when winter rains have raised the water level in Redwood Creek, visitors may see, but not catch, huge salmon and steelhead fighting their tortuous way up the rapids to the spawning beds within the monument.

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